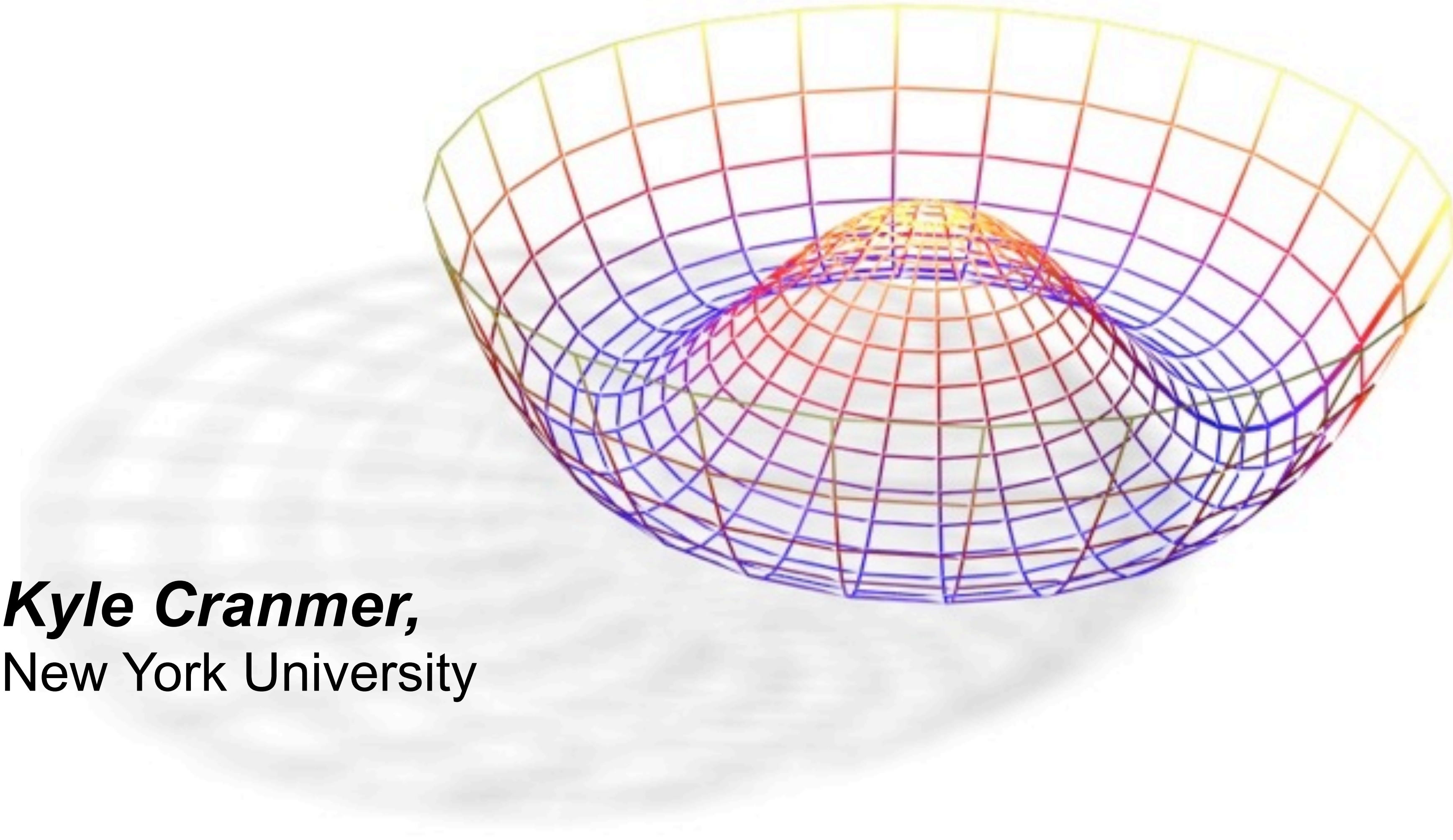
CENTER FOR
COSMOLOGY AND
PARTICLE PHYSICS

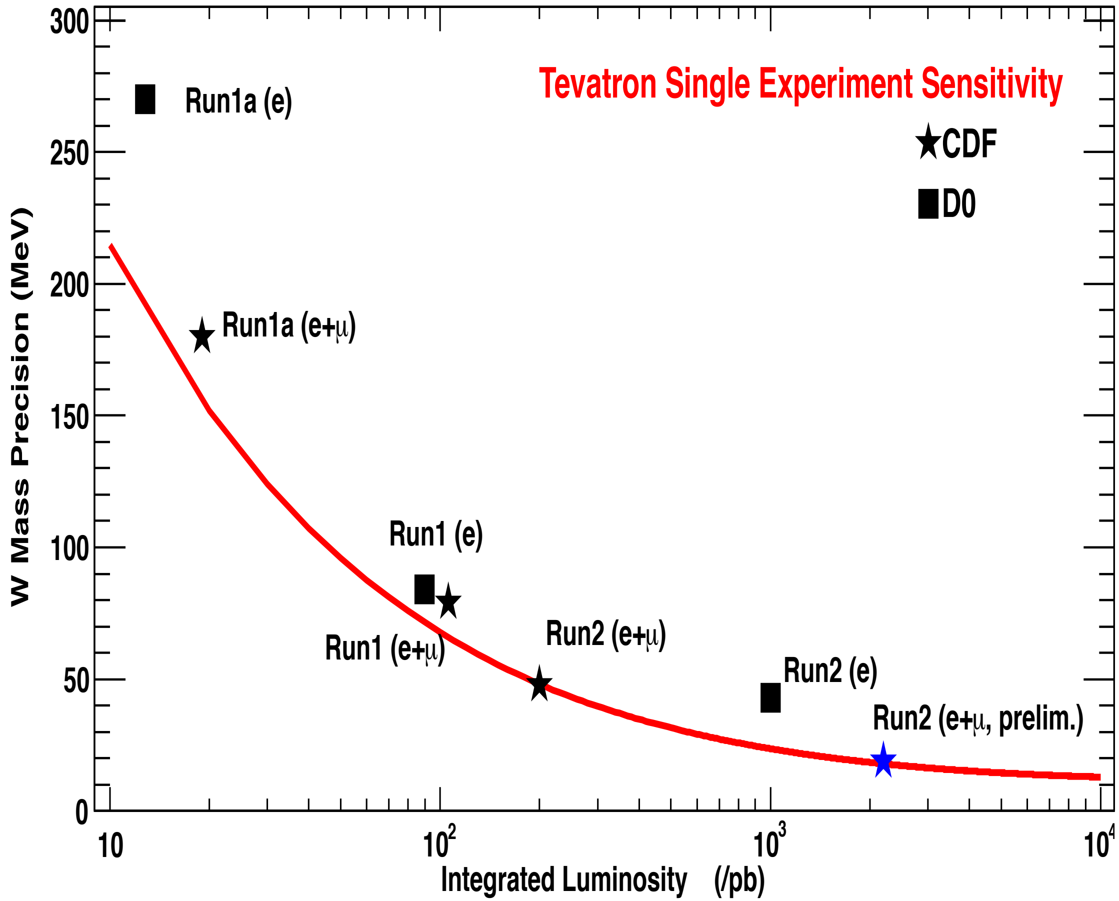
Higgs Couplings @ the LHC

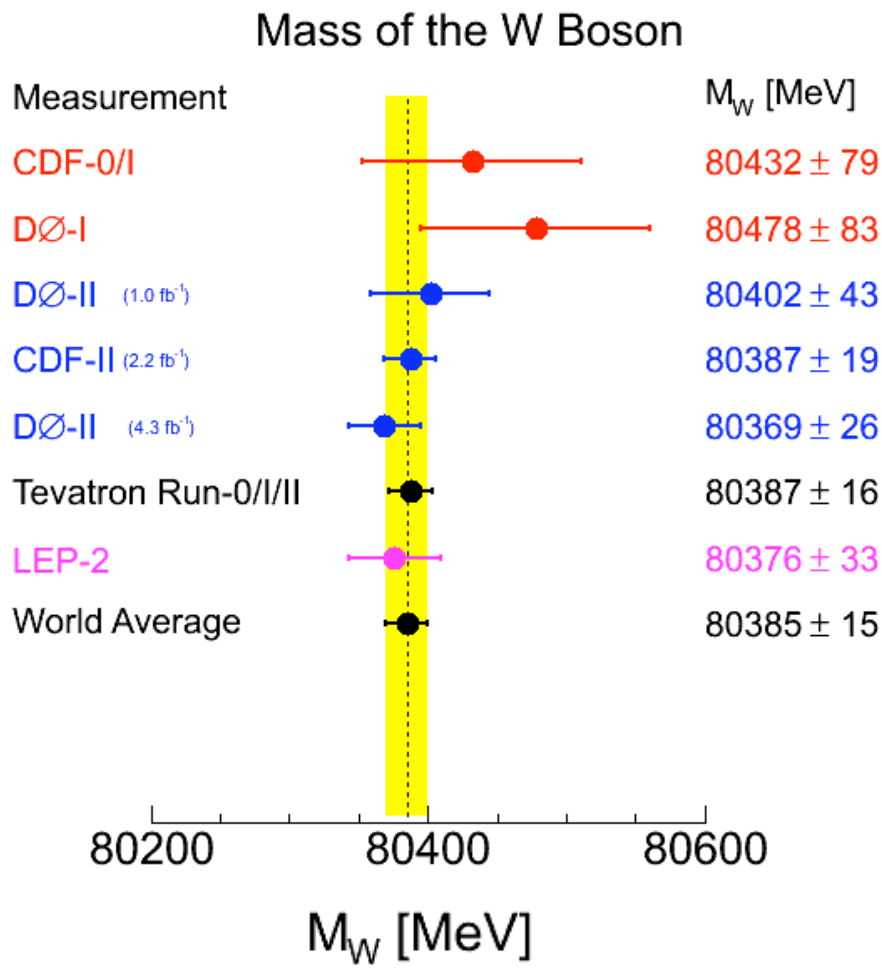


Kyle Cranmer,
New York University

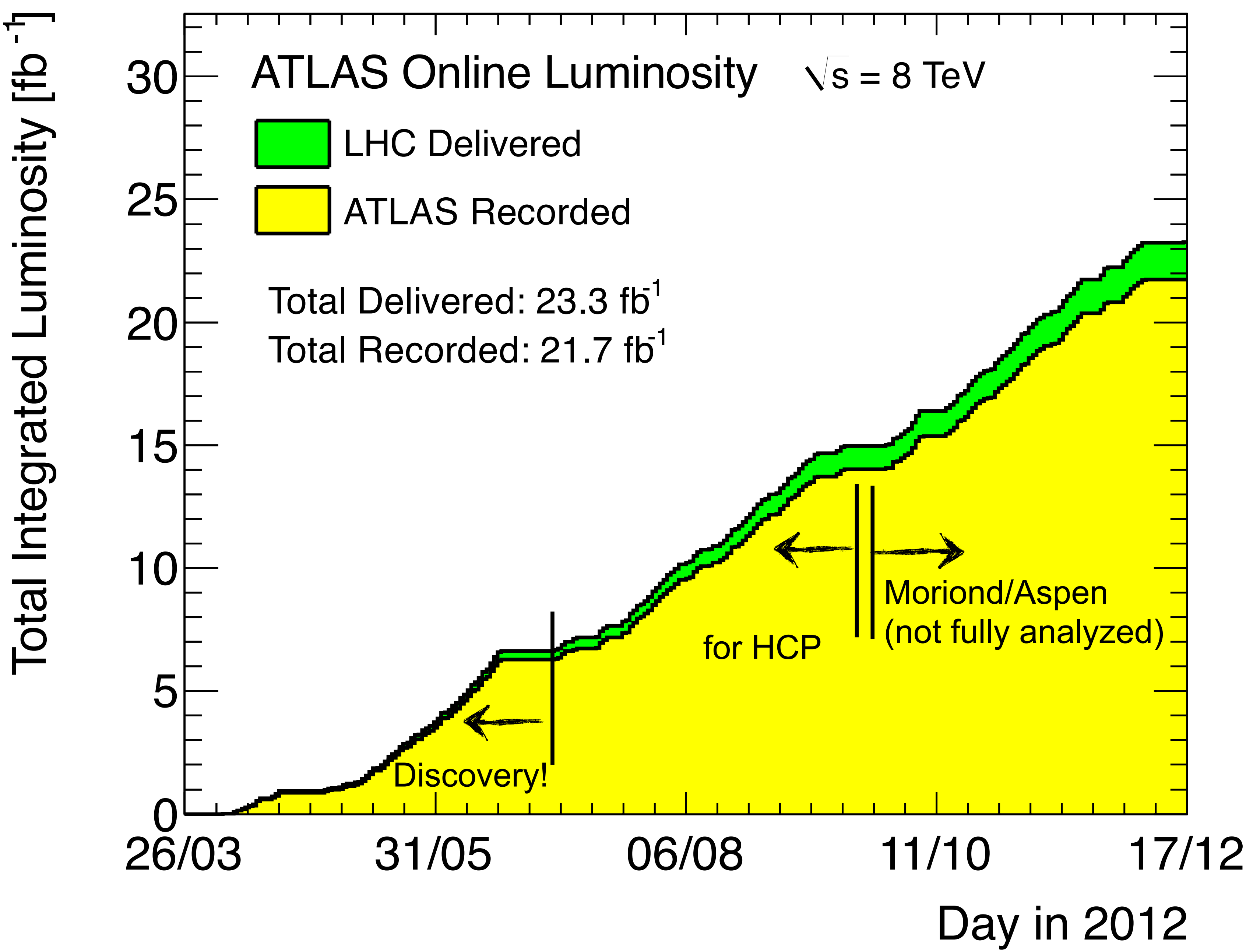
People are clever...

Surprising that most precise measurement of W-mass performed with a hadron collider

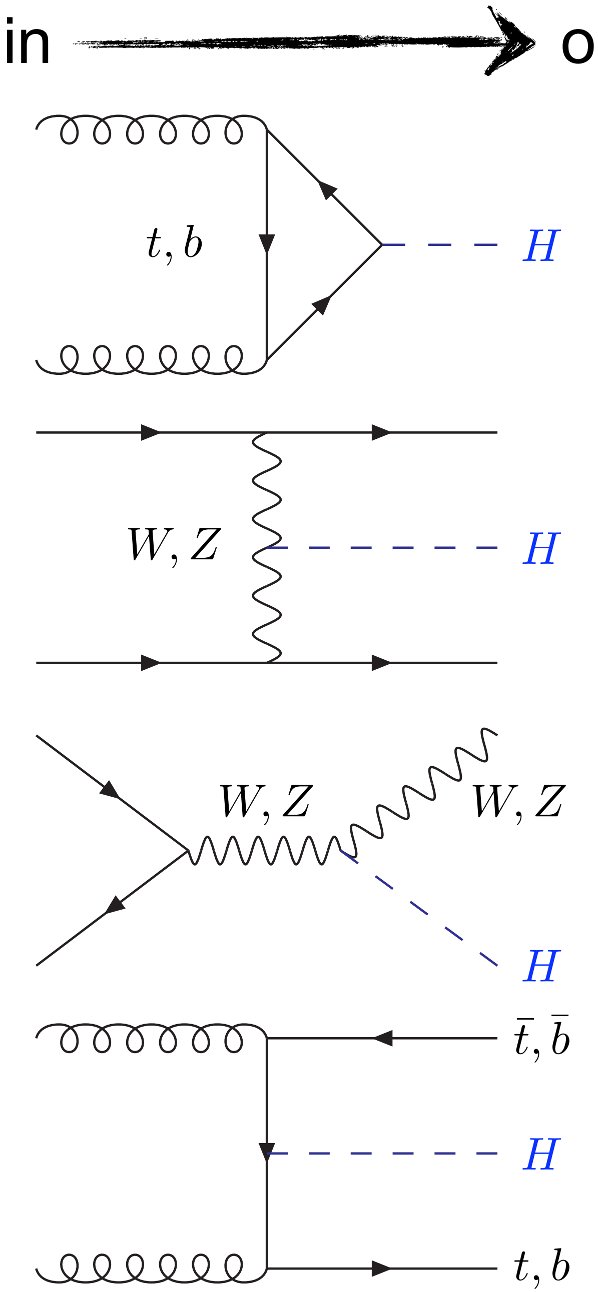


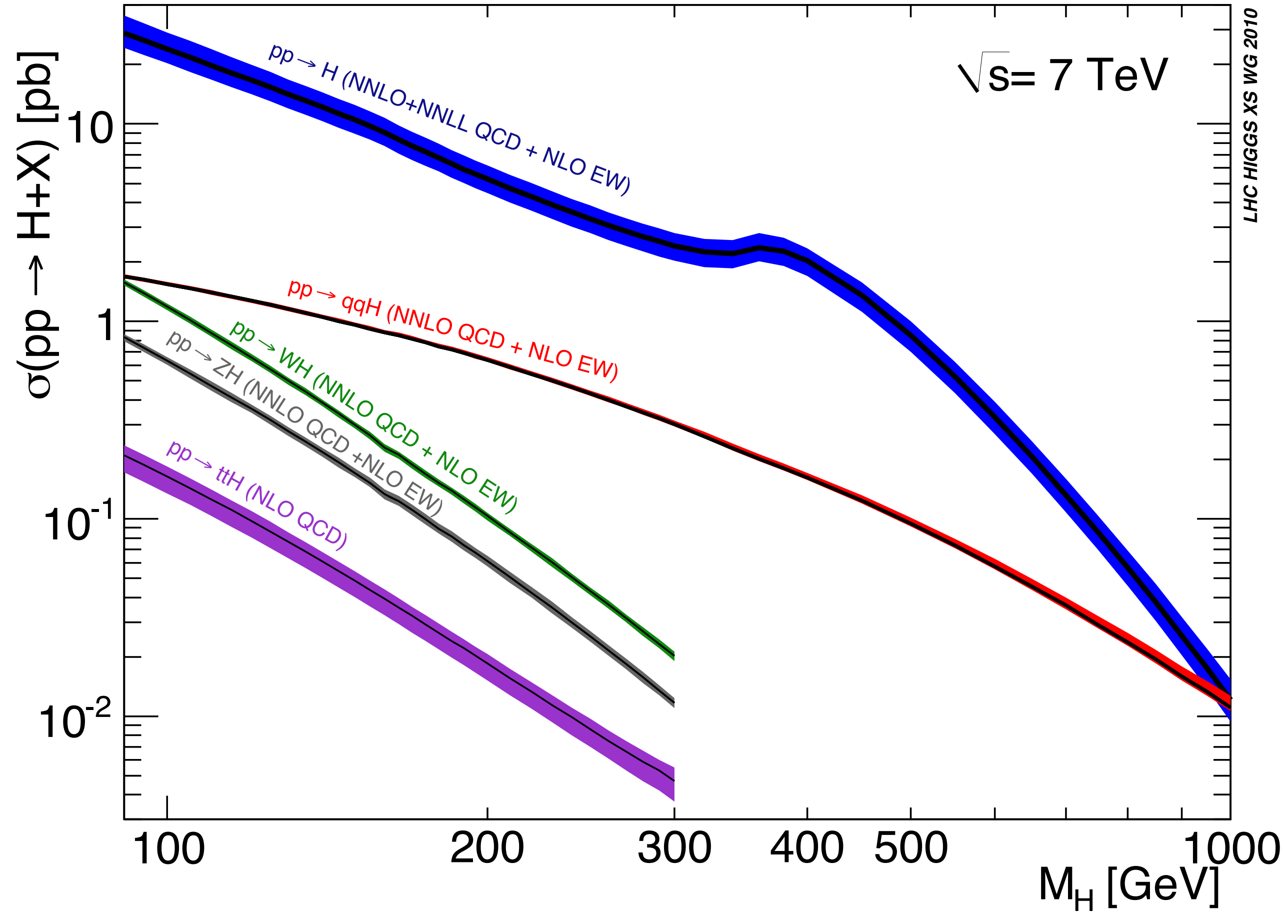


Prospects for the end of the year and beyond



Standard Model Higgs Properties



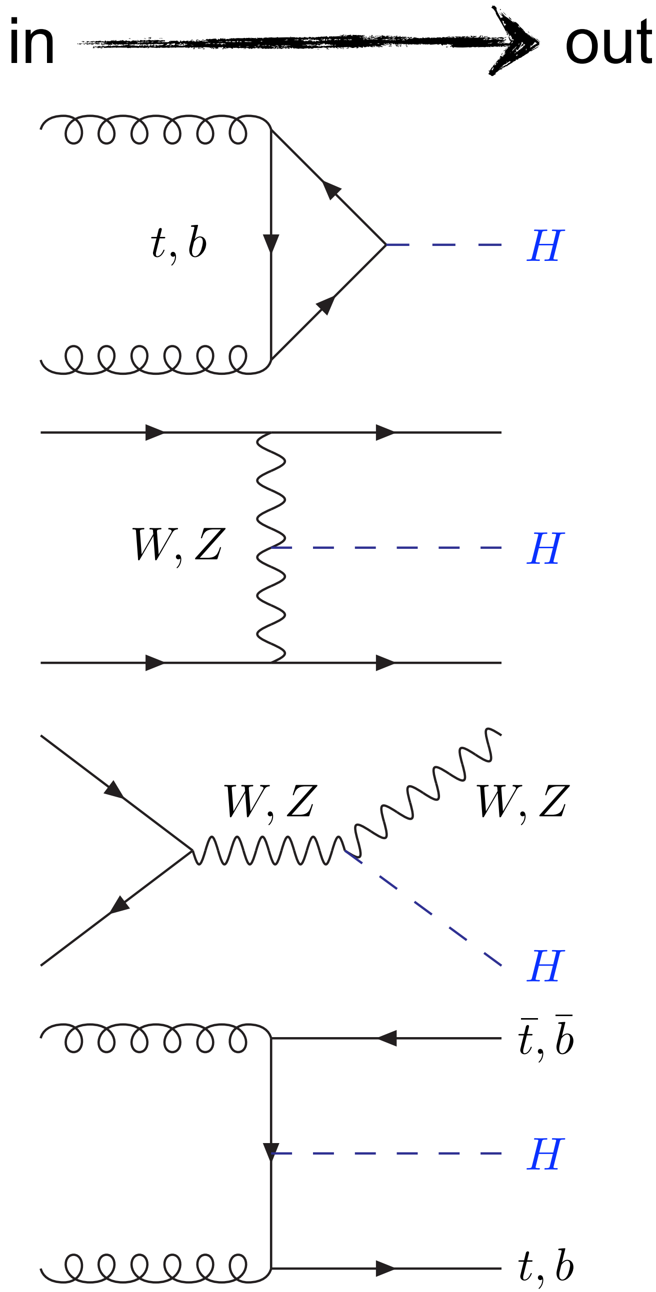


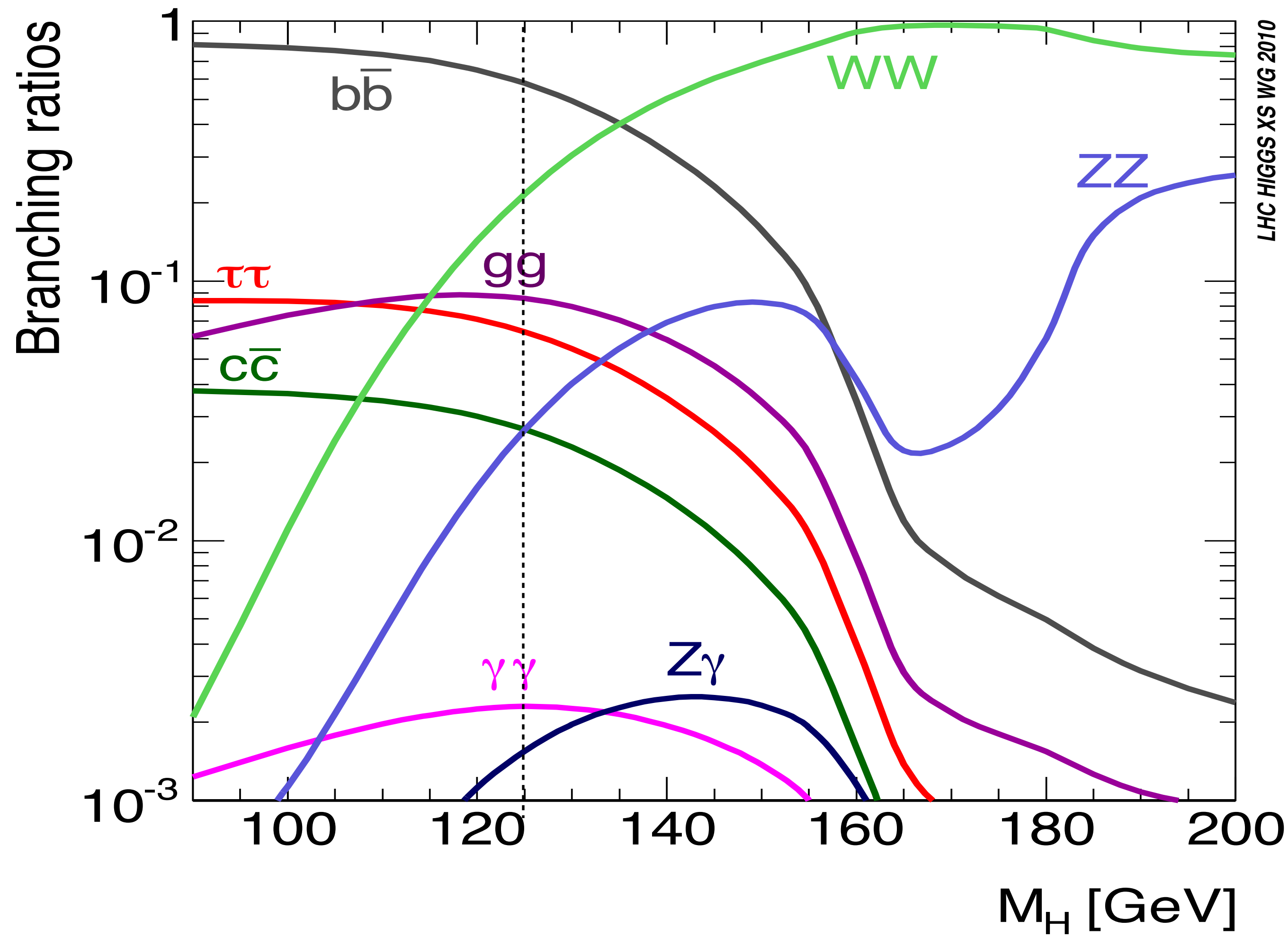
Gluon fusion: produced with little pT

Vector boson fusion: hard jets, high pT

Associated: extra handle from leptons

Standard Model Higgs Properties



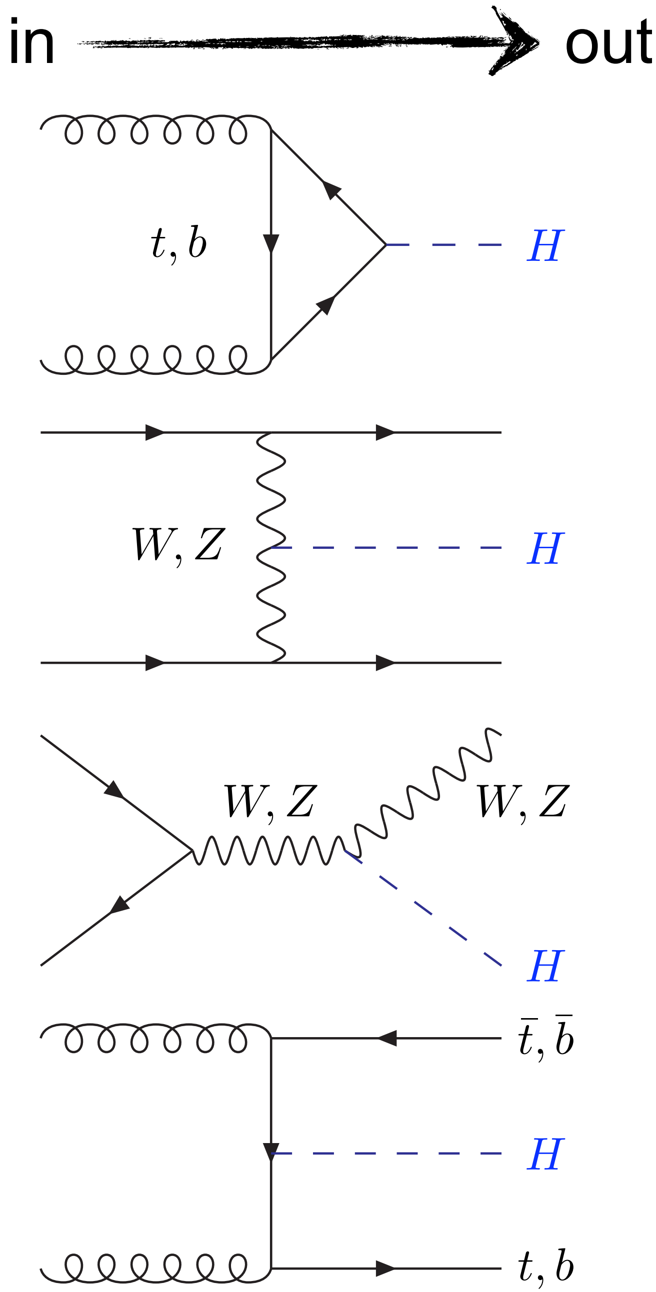


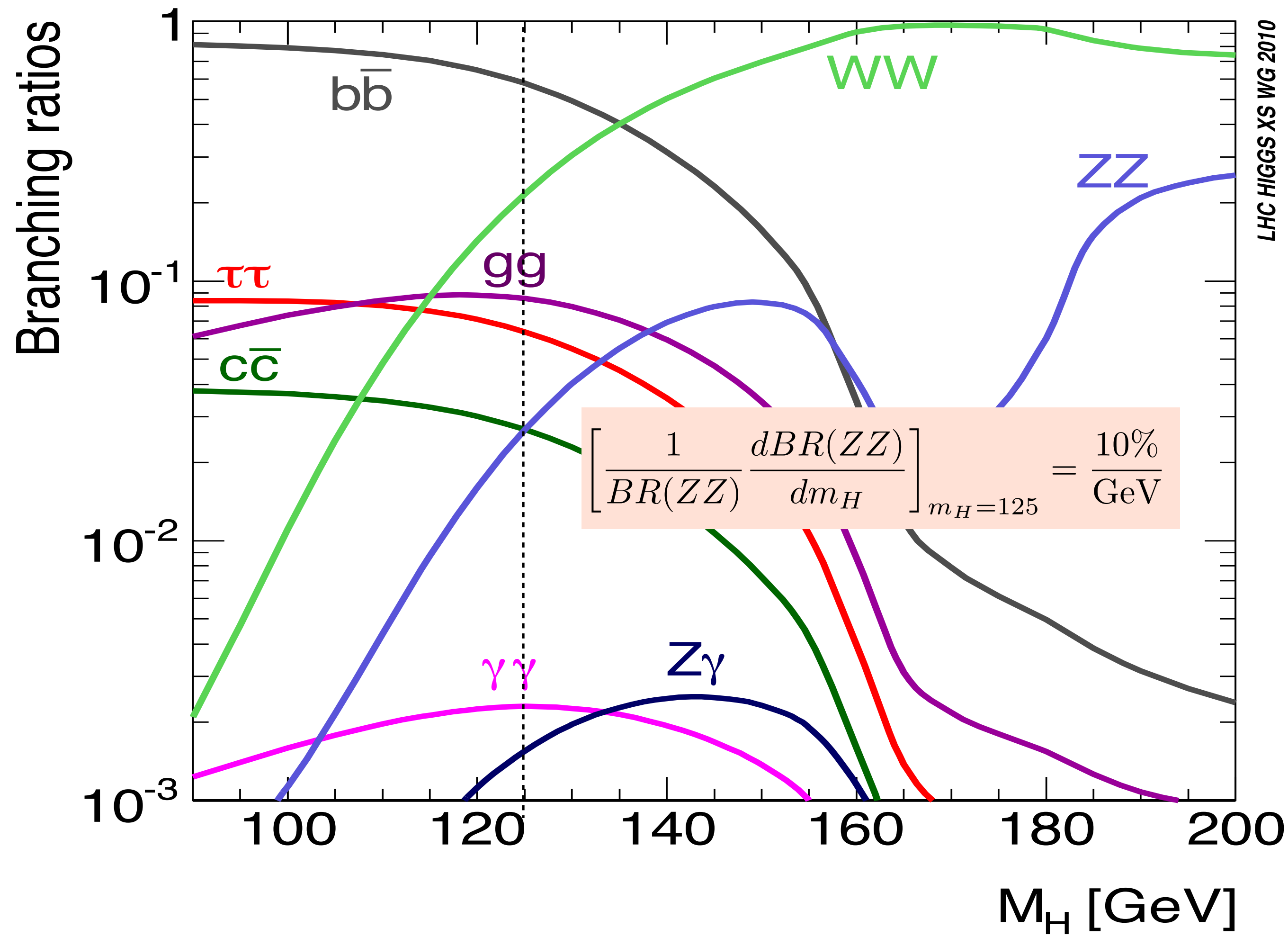
Many decays accessible at 126 GeV

bb dominates, but is difficult

$\gamma\gamma$ small, but clean

Standard Model Higgs Properties





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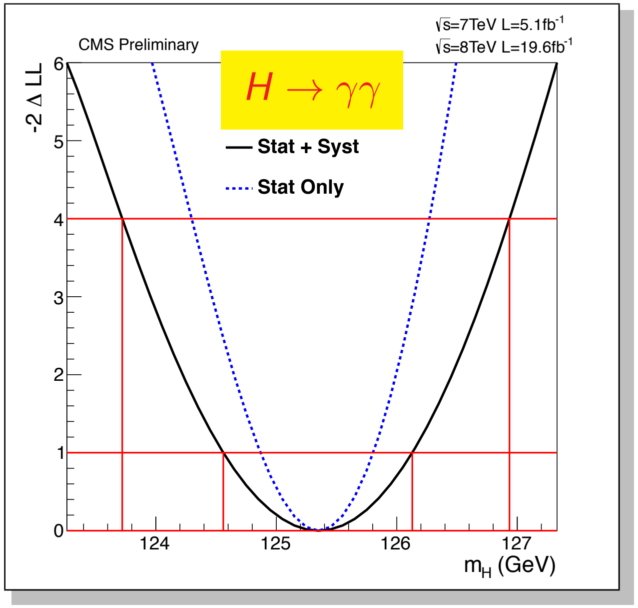
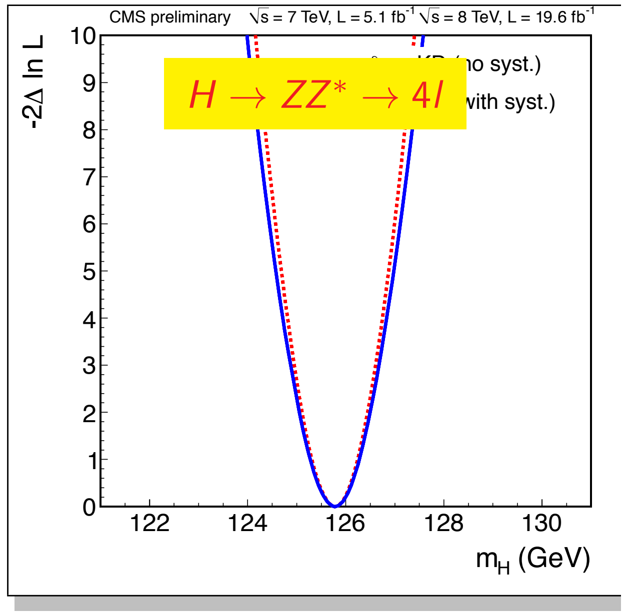
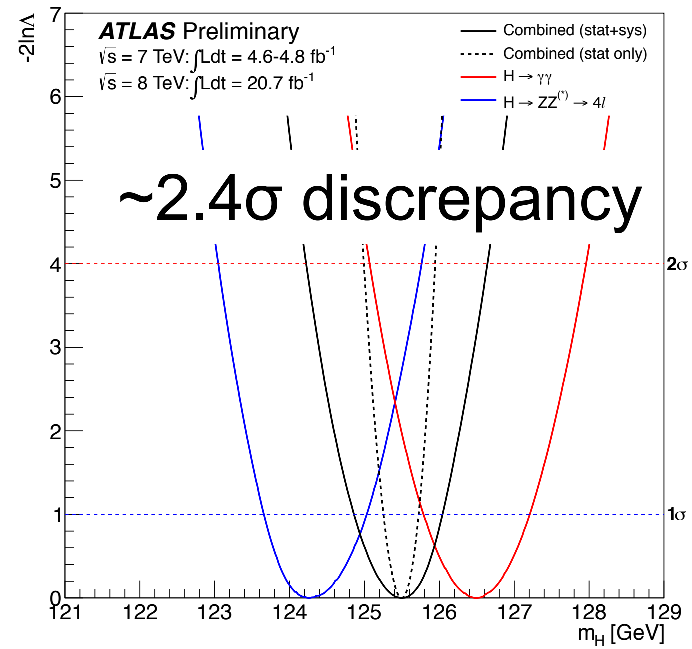
Mass measurement







$m_X = 125.4 \pm 0.5\ (stat) \pm 0.6\ (syst)\ GeV$ $\quad m_X = 125.8 \pm 0.5\ (stat) \pm 0.2\ (syst)\ GeV$

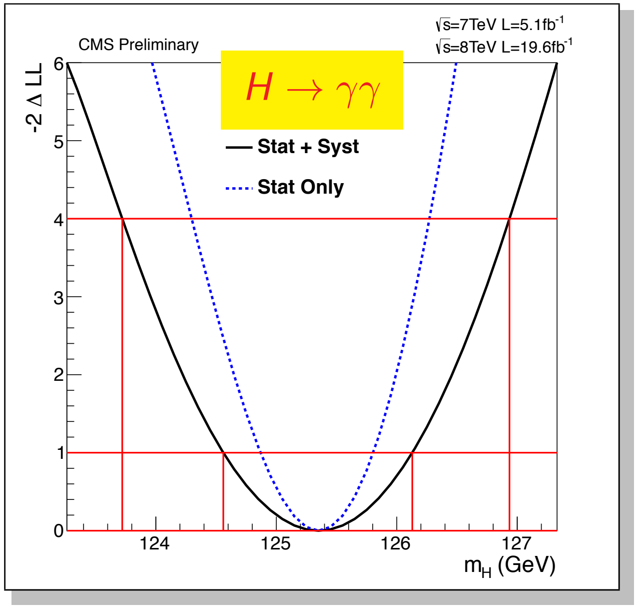
Mass from $H \to \tau\tau$ $(m_X = 120^{+9}_{-6}(stat) \pm 4(sys)\ GeV)$ consistent

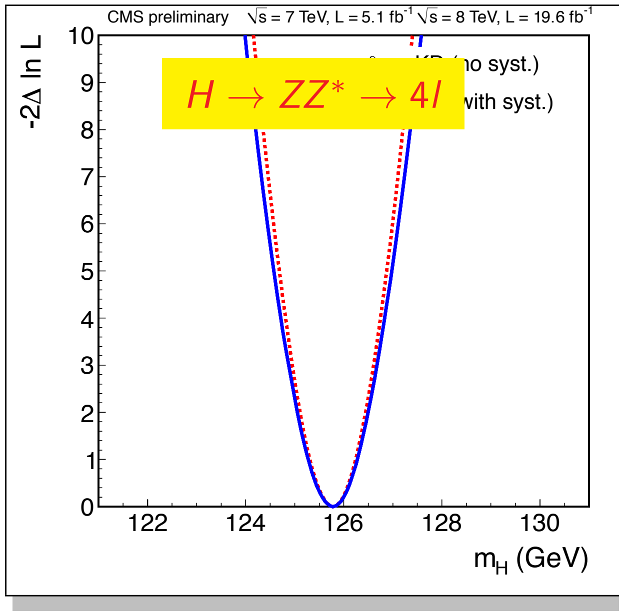
	$H \to ZZ^{(*)} \to \ell\ell\ell\ell$	$H \to \gamma\gamma$
$\hat{m}_H$ (GeV)	$124.3^{+0.6}_{-0.5}(\text{stat})^{+0.5}_{-0.3}(\text{sys})$	$126.8 \pm 0.2(\text{stat}) \pm 0.7(\text{sys})$

Combined mass:

$125.5 \pm 0.2(\text{stat})^{+0.5}_{-0.6}(\text{sys})$ GeV

Mass measurement





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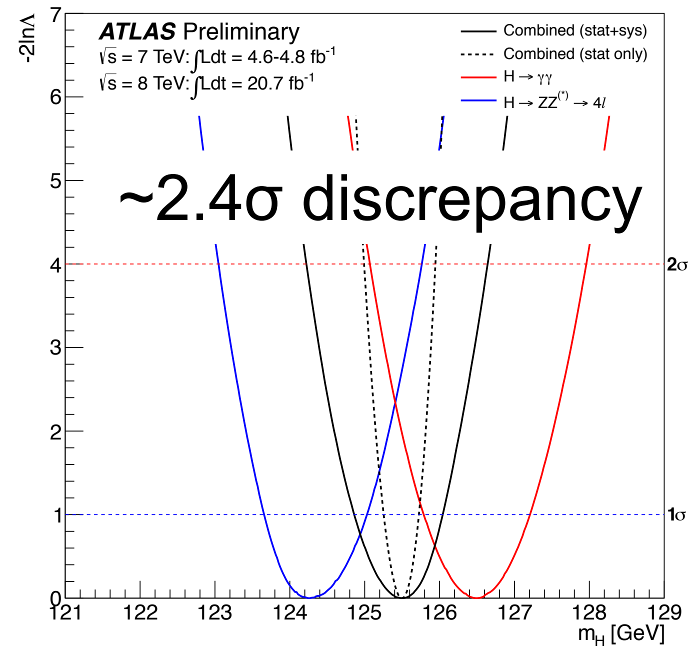

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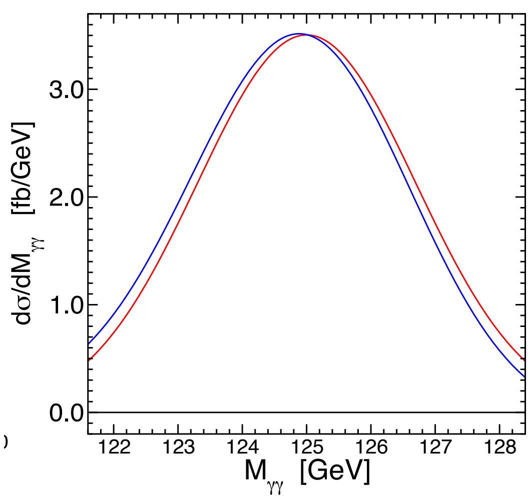
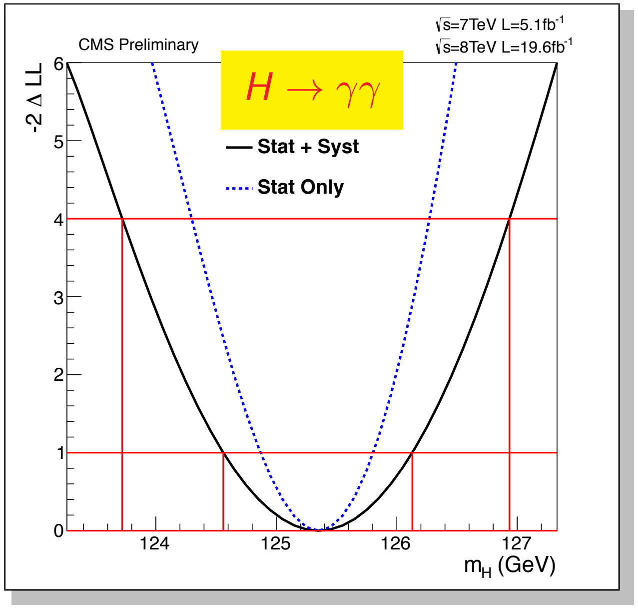


Dixon & Siu: hep-ph/0302233
σ change due to (2-loop) interference of continuum

S. Martin arXiv:1208.1533
shift of mass peak ~100 MeV (assuming SM Higgs)

Mass measurement



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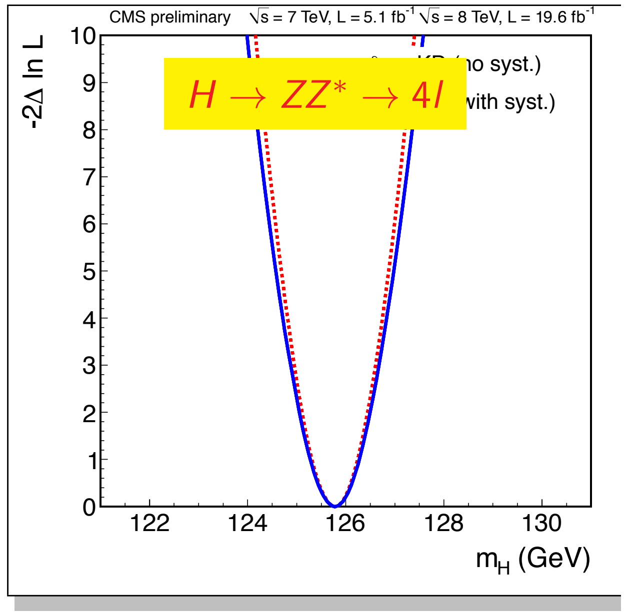

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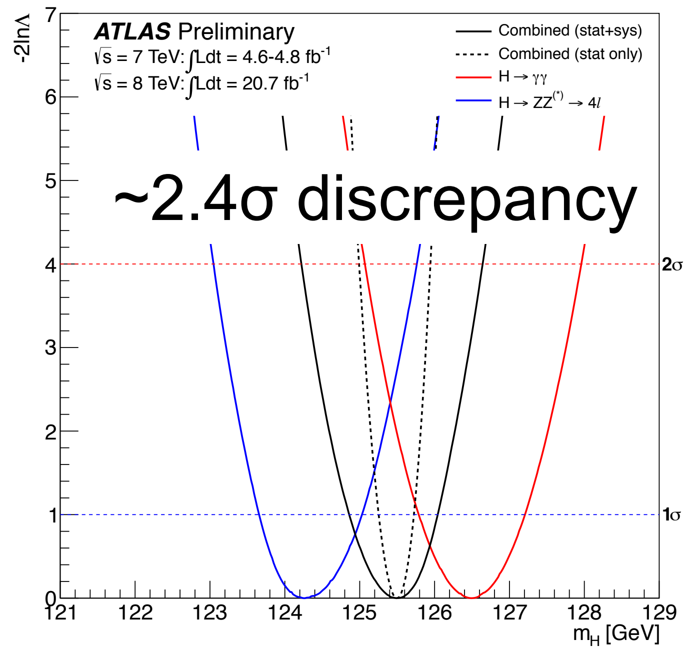

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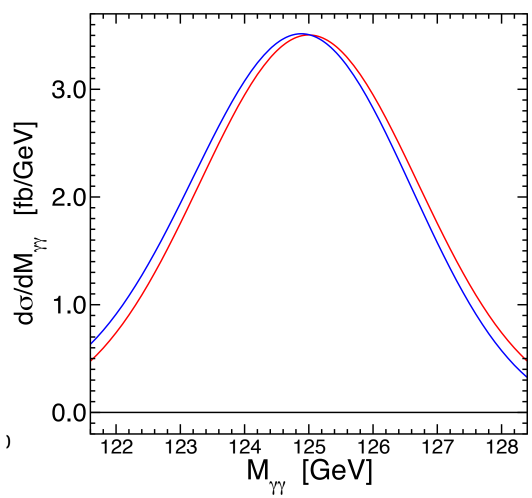

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Does this give a handle on total width or complex phases from new physics?

Overview of the channels

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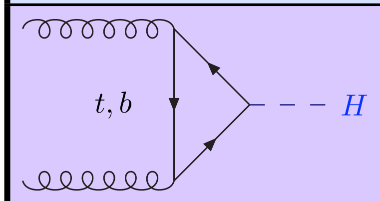
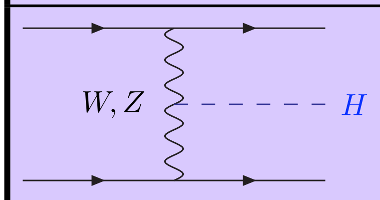
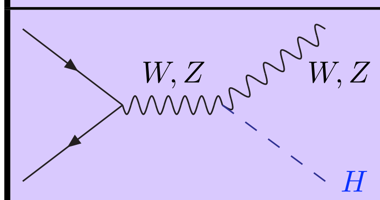
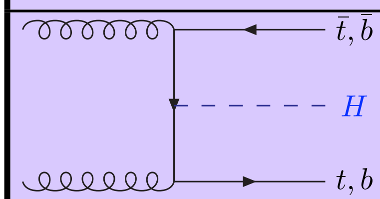
	γγ	ZZ	WW	Zγ	gg	bb	ττ
							
							
							
							

done

not yet

difficult

Details

Channels are sub-divided to enhance sensitivity either for experimental reasons or take advantage of production features

Higgs Boson Decay	Subsequent Decay	Sub-Channels	$\int L\,dt$ [fb^{-1}]	Ref.
		2011 $\sqrt{s}$ =7 TeV		
$H \to ZZ^{(*)}$	4ℓ	$\{4e, 2e2\mu, 2\mu2e, 4\mu$, 2-jet VBF, ℓ-tag$\}$	4.6	[8]
$H \to \gamma\gamma$	–	10 categories $\{p_{\mathrm{Tt}} \otimes \eta_\gamma \otimes$ conversion$\} \oplus \{$2-jet VBF$\}$	4.8	[7]
$H \to WW^{(*)}$	$\ell\nu\ell\nu$	$\{ee, e\mu, \mu e, \mu\mu\} \otimes \{$0-jet, 1-jet, 2-jet VBF$\}$	4.6	[9]
$H \to \tau\tau$	$\tau_{\mathrm{lep}}\tau_{\mathrm{lep}}$	$\{e\mu\} \otimes \{$0-jet$\} \oplus \{\ell\ell\} \otimes \{$1-jet, 2-jet, $p_{\mathrm{T},\tau\tau} > 100$ GeV, $VH\}$	4.6	[10]
	$\tau_{\mathrm{lep}}\tau_{\mathrm{had}}$	$\{e, \mu\} \otimes \{$0-jet, 1-jet, $p_{\mathrm{T},\tau\tau} > 100$ GeV, 2-jet$\}$	4.6	
	$\tau_{\mathrm{had}}\tau_{\mathrm{had}}$	$\{$1-jet, 2-jet$\}$	4.6	
$VH \to Vbb$	$Z \to \nu\nu$	$E_{\mathrm{T}}^{\mathrm{miss}} \in \{120-160, 160-200, \geq 200$ GeV$\} \otimes \{$2-jet, 3-jet$\}$	4.6	[11]
	$W \to \ell\nu$	$p_{\mathrm{T}}^{W} \in \{< 50, 50-100, 100-150, 150-200, \geq 200$ GeV$\}$	4.7	
	$Z \to \ell\ell$	$p_{\mathrm{T}}^{Z} \in \{< 50, 50-100, 100-150, 150-200, \geq 200$ GeV$\}$	4.7	
		2012 $\sqrt{s}$ =8 TeV		
$H \to ZZ^{(*)}$	4ℓ	$\{4e, 2e2\mu, 2\mu2e, 4\mu$, 2-jet VBF, ℓ-tag$\}\}$	20.7	[8]
$H \to \gamma\gamma$	–	14 categories $\{p_{\mathrm{Tt}} \otimes \eta_\gamma \otimes$ conversion$\} \oplus \{$2-jet VBF$\} \oplus \{\ell$-tag, $E_{\mathrm{T}}^{\mathrm{miss}}$-tag, 2-jet VH$\}$	20.7	[7]
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Signal strength

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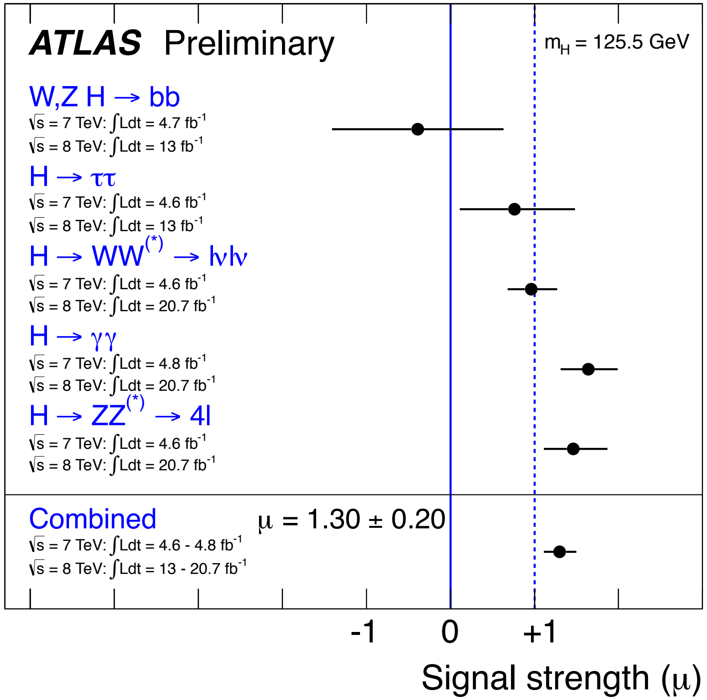
Global combined μ scales all modes w.r.t. SM expectation

- good for discovery, but a blunt instrument for probing deviations

Several goodness-of-fit tests - depend on #d.o.f. considered

- Individual μ_i compatible with combined $\hat{\mu}$ at 13% (and μ=1 at 8%)
- Combined $\hat{\mu}$ compatible with μ = 1 within 9%

Higgs Decay Mode	$\hat{\mu}$ (m_H=125.5 GeV)
$VH \to Vbb$	-0.4 ± 1.0
$H \to \tau\tau$	0.8 ± 0.7
$H \to WW^{(*)}$	1.0 ± 0.3
$H \to \gamma\gamma$	1.6 ± 0.3
$H \to ZZ^{(*)}$	1.5 ± 0.4
Combined	1.30 ± 0.20



$$\mu_{\rm obs} = 1.65^{+0.24}_{-0.24}(\text{stat})^{+0.25}_{-0.18}(\text{syst})$$

$$\mu_{\rm obs} = 1.01 \pm 0.21\,(\text{stat.}) \pm 0.19\,(\text{theo. syst.}) \pm 0.12\,(\text{expt. syst.}) \pm 0.04\,(\text{lumi.})$$

VBF 2-photon candidate

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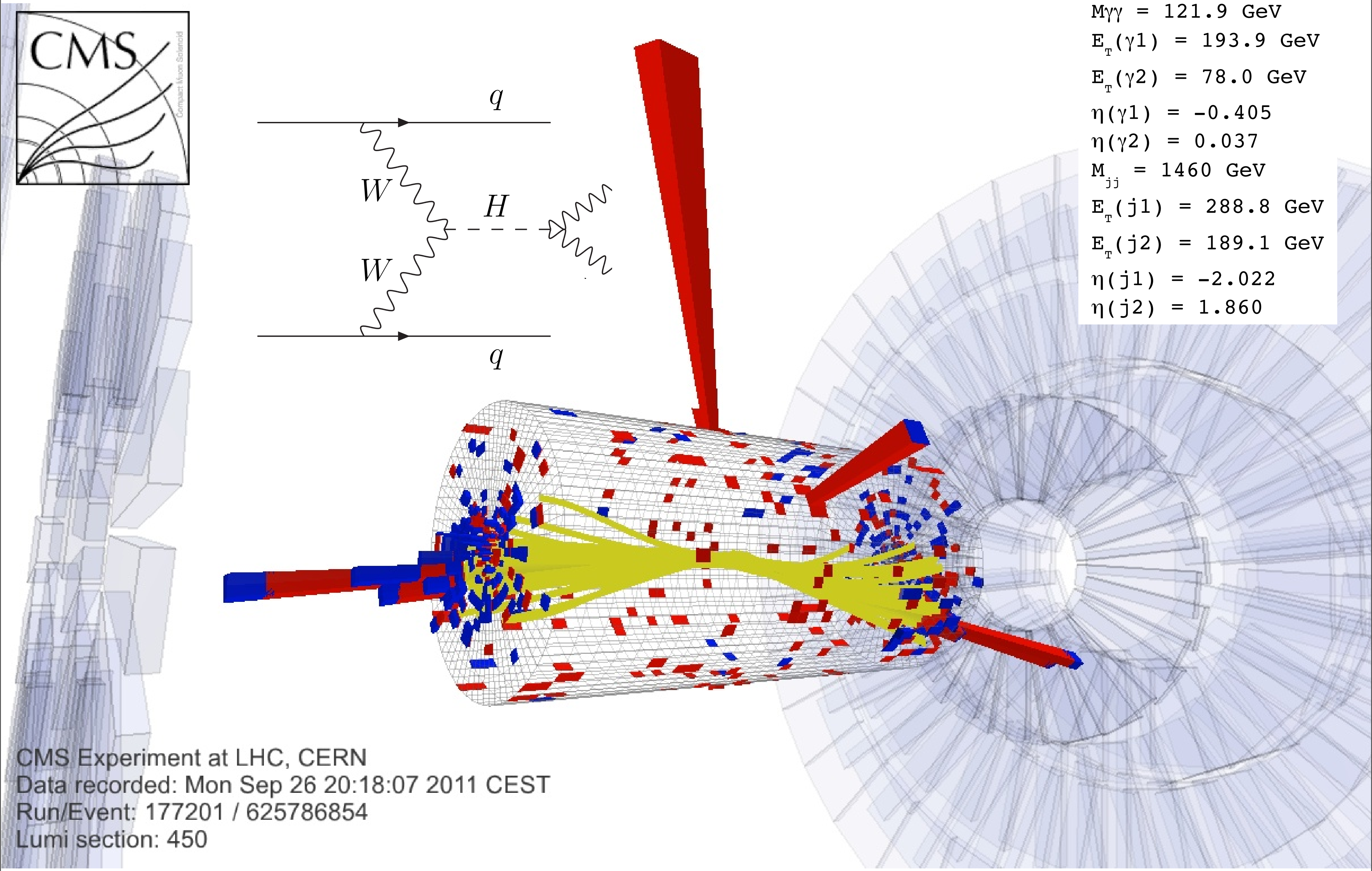
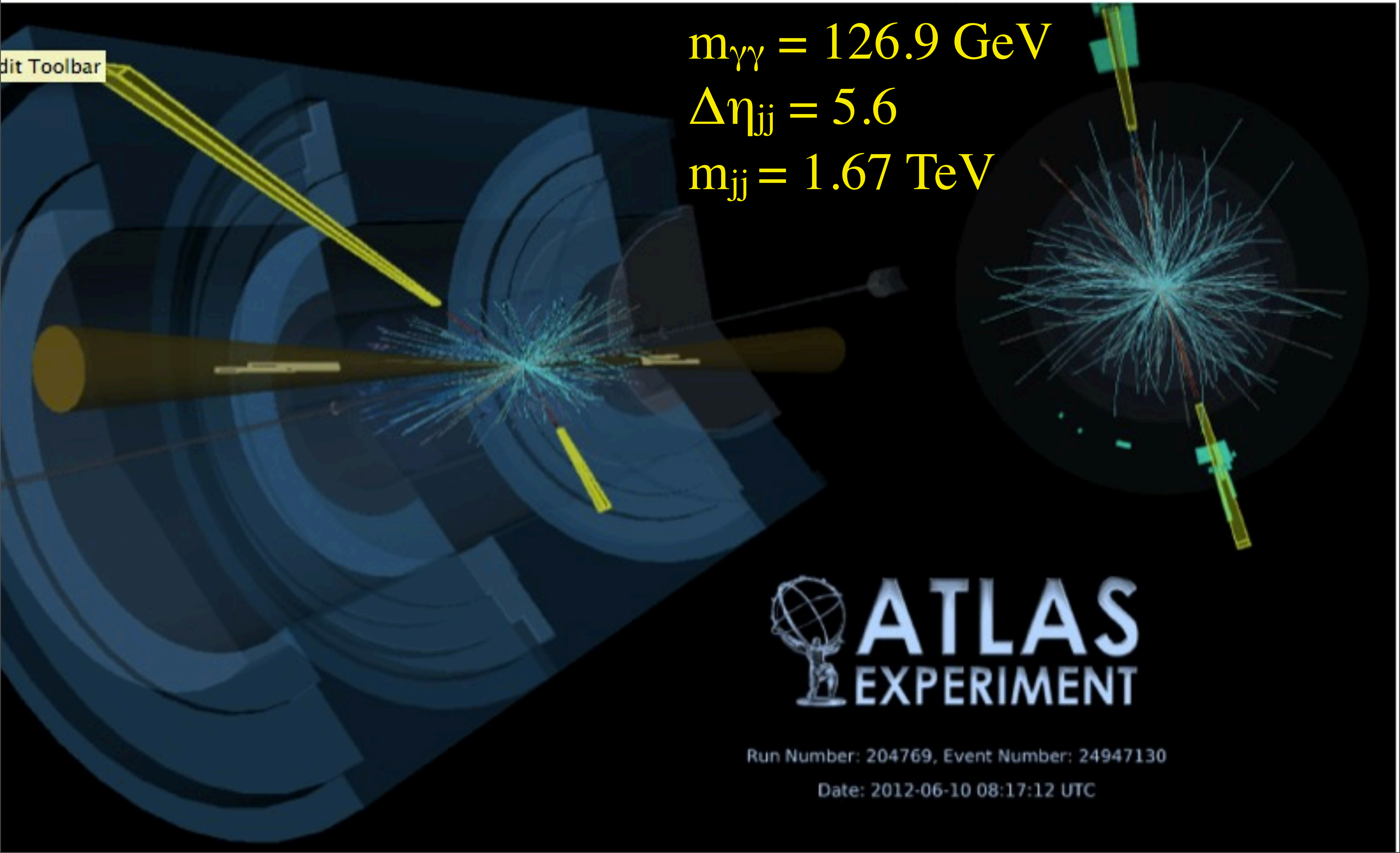


$M_{\gamma\gamma}$ = 121.9 GeV
$E_T(\gamma 1)$ = 193.9 GeV
$E_T(\gamma 2)$ = 78.0 GeV
$\eta(\gamma 1)$ = -0.405
$\eta(\gamma 2)$ = 0.037
M_{jj} = 1460 GeV
$E_T(j1)$ = 288.8 GeV
$E_T(j2)$ = 189.1 GeV
$\eta(j1)$ = -2.022
$\eta(j2)$ = 1.860

VBF 2-photon candidate

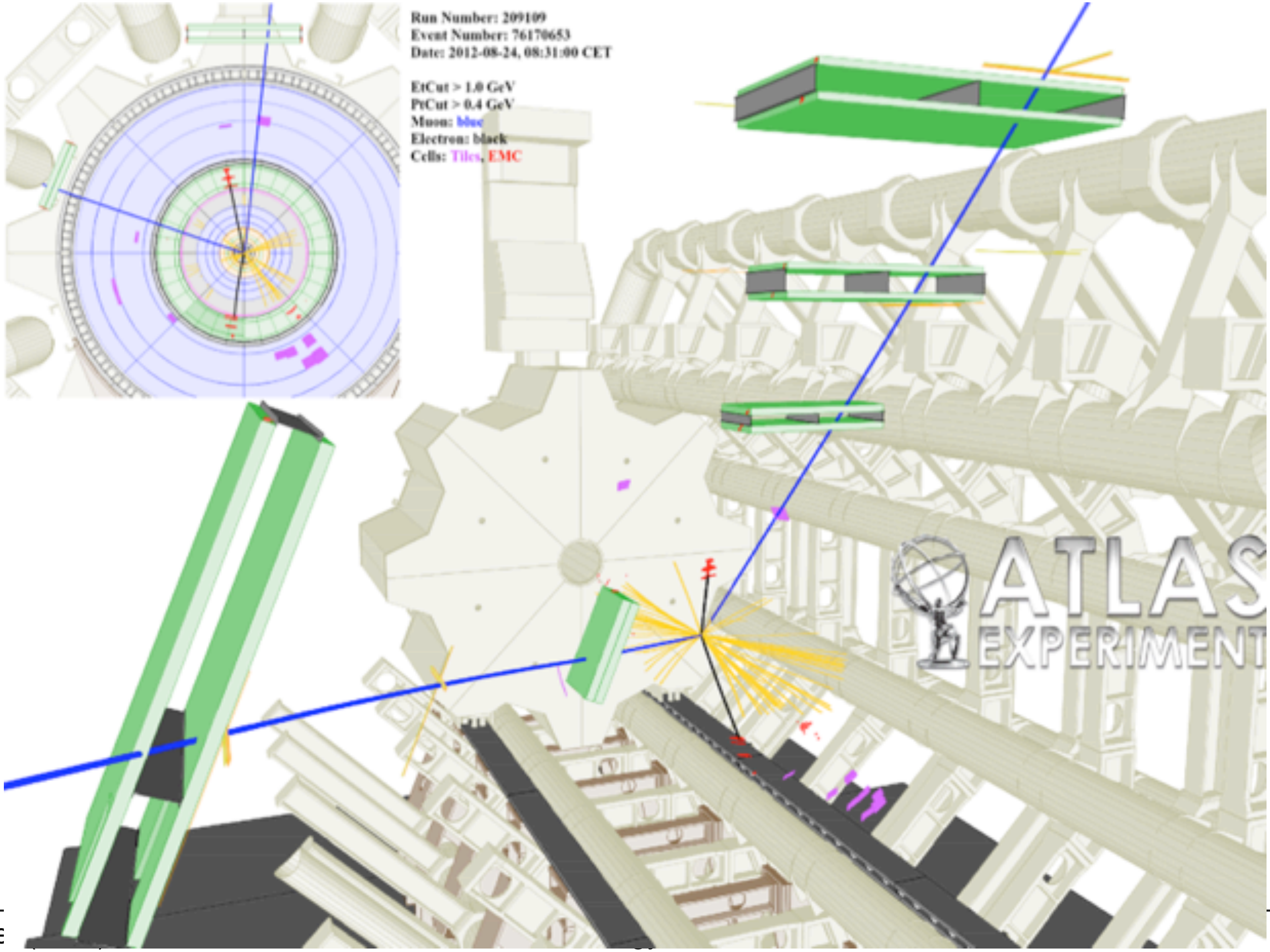
About 12 Higgs events expected in VBF-like categories



VBF H→ 4l candidate

no candidates in lepton-tagged categories

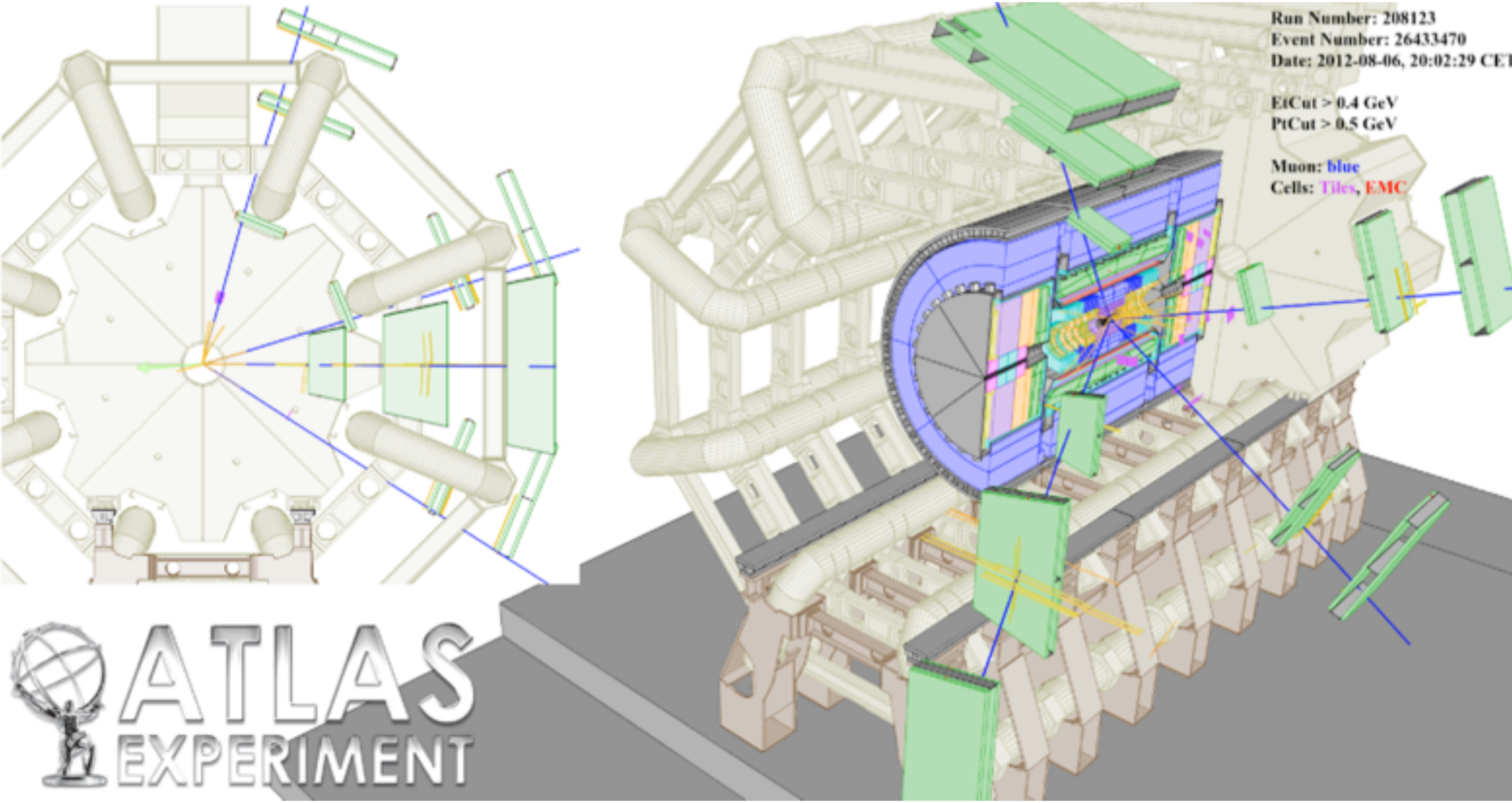
1 VBF candidate observed (m_{4l}=123.5 GeV) [0.7 expected, S/B~5]



Our SM bias?

ATLAS does not have a Z(→ νν) H(→4l) b/c sensitivity in SM is small

m_{4l}=123.5 GeV, ETmiss=121.3 GeV



"You think you know what you want...

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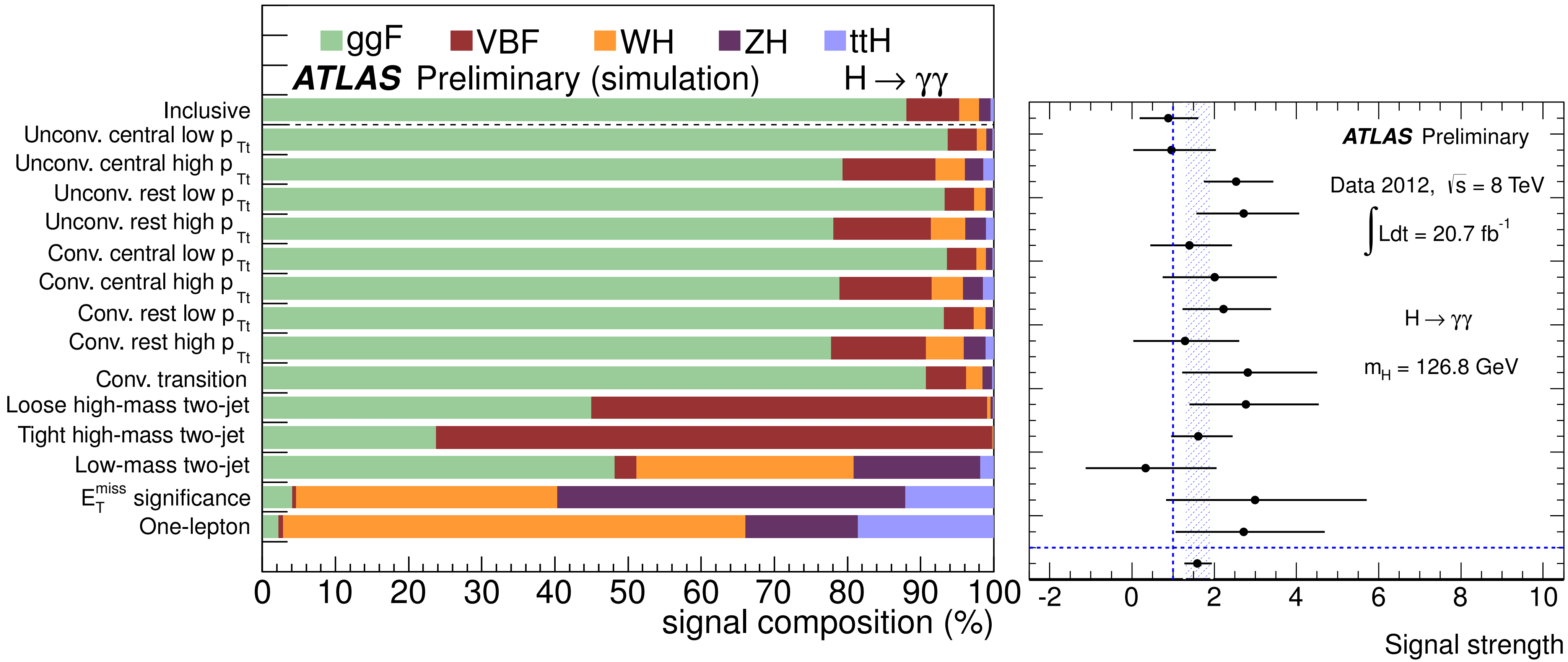


$$n^k_{\text{Signal}} = \left(\sum \mu_i \sigma_{i,SM} \times A^k_{if} \times \varepsilon^k_{if}\right) \times \mu_f \mathcal{B}_{f,SM} \times \mathcal{L}^k$$

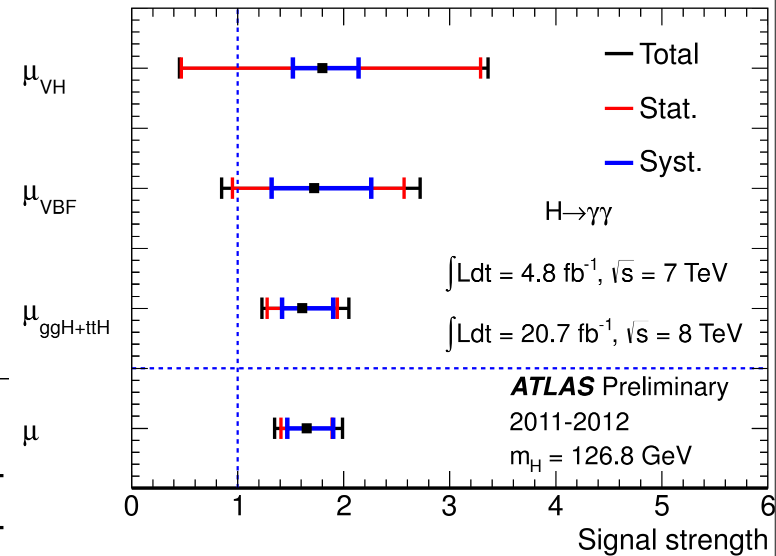
- $\sigma_i = \mu_i \sigma_{i,SM}$ is the i^{th} hypothesized production cross section
- $\mathcal{B}_f = \mu_f \mathcal{B}_{f,SM}$ is the f^{th} hypothesized branching fraction
- Detector acceptance A^k_{if}, reconstruction efficiency ε^k_{if}, and integrated luminosity $\mathcal{L}^k$ are fixed by above assumptions

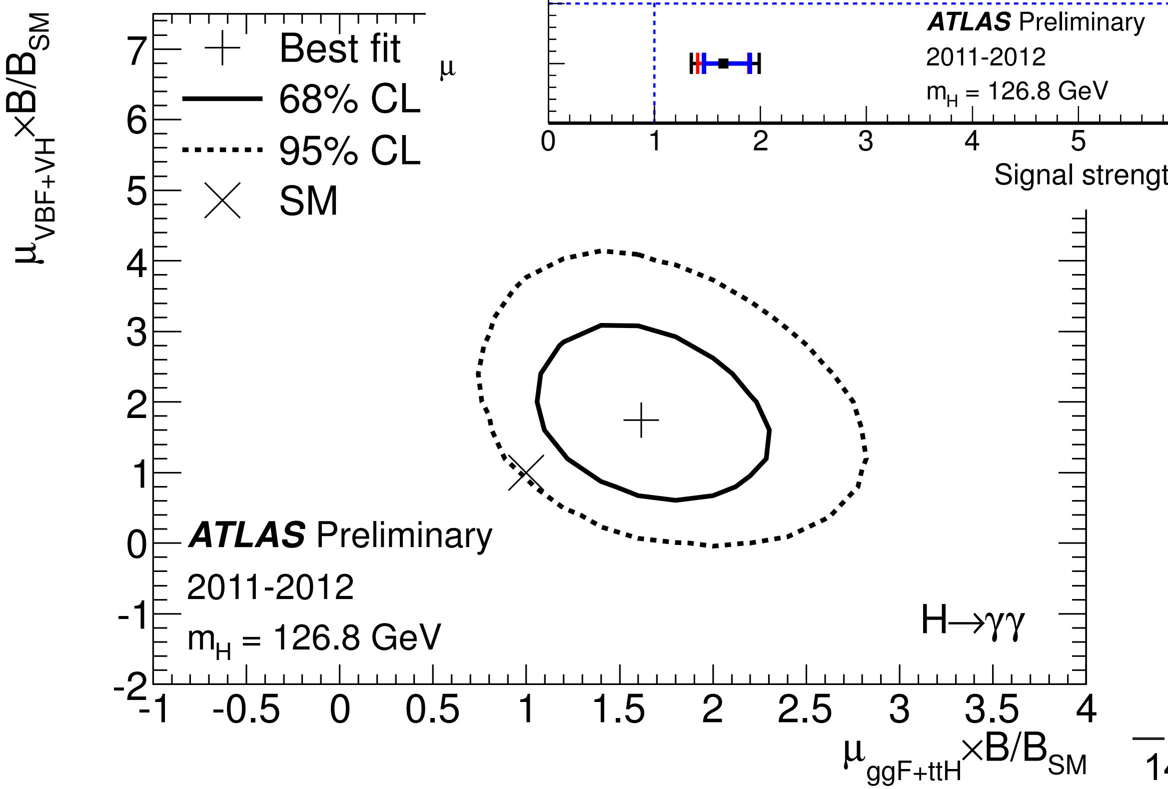
... let me tell you what you want”

The systematics are correlated, which leads to a non-trivial migration of events between categories.

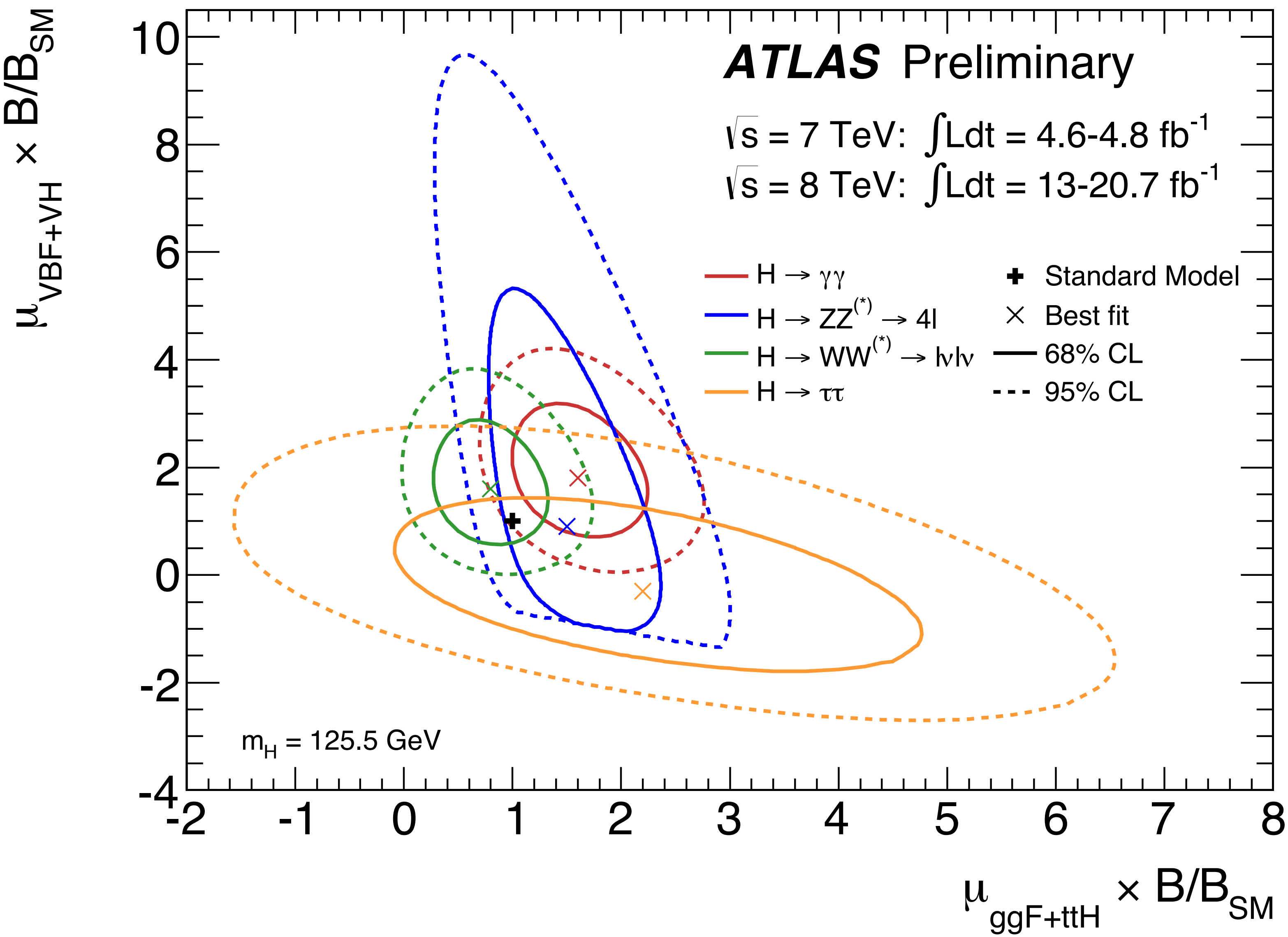
- We can disentangle the different production modes

Systematic uncertainties	Category	Value(%)			Constraint
Underlying Event	Tight high-mass two-jet	ggF: ±8.8	VBF: ±2.0	VH, ttH: ±8.8	Log-normal
	Loose high-mass two-jet	ggF: ±12.8	VBF: ±3.3	VH, ttH: ±12.8	
	Low-mass two-jet	ggF: ±12	VBF: ±3.9	VH, ttH: ±12	
Jet Energy Scale	Low p_{Tt}	ggF: −0.1	VBF: −1.0	Others: −0.1	Gaussian
	High p_{Tt}	ggF: −0.7	VBF: −1.3	Others: +0.4	
	Tight high-mass two-jet	ggF: +11.8	VBF: +6.7	Others: +20.2	
	Loose high-mass two-jet	ggF: +10.7	VBF: +4.0	Others: +5.7	
	Low-mass two-jet	ggF: +4.7	VBF: +2.6	Others: 1.4	
	E_T^{miss}significance	ggF: 0.0	VBF: 0.0	Others: 0.0	
	one-lepton	ggF: 0.0	VBF: 0.0	Others: −0.1	
Jet Energy Resolution	Low p_{Tt}	ggF: 0.0	VBF: 0.2	Others: 0.0	Gaussian
	High p_{Tt}	ggF: −0.2	VBF: 0.2	Others: 0.6	
	Tight high-mass two-jet	ggF: 3.8	VBF: −1.3	Others: 7.0	
	Loose high-mass two-jet	ggF: 3.4	VBF: −0.7	Others: 1.2	
	Low-mass two-jet	ggF: 0.5	VBF: 3.4	Others: −1.3	
	E_T^{miss}significance	ggF: 0.0	VBF: 0.0	Others: 0.0	
	one-lepton	ggF: −0.9	VBF: −0.5	Others: −0.1	
η^* modelling		Tight high-mass two-jet: +7.6			Gaussian
		Loose high-mass two-jet: +6.2			
Dijet angular modelling		Tight high-mass two-jet: +12.1			Gaussian
		Loose high-mass two-jet: +8.5			
Higgs p_T		Low p_{Tt}: +1.3			Gaussian
		High p_{Tt}: −10.2			
		Tight high-mass two-jet: −10.4			
		Loose high-mass two-jet: −8.5			
		Low-mass two-jet: −12.5			
		E_T^{miss}significance: −2.0			
		one-lepton : −4.0			
Material Mismodelling		Unconv: −4.0	Conv: +3.5		Gaussian
JVF	Loose High-mass two-jet	ggF: −1.2	VBF: −0.3	Others: −1.2	Gaussian
	Low-mass two-jet	ggF: −2.3	VBF: −2.4	Others: −2.3	
E_T^{miss}	E_T^{miss}significance	ggF: +66.4	VBF: +30.7	VH, ttH: +1.2	Gaussian
e reco and identification		one-lepton: < 1			Gaussian
e Escale and resolution		one-lepton: < 1			Gaussian
μ reco, ID resolution		one-lepton: < 1			Gaussian
μ spectrometer resolution		one-lepton: 0			Gaussian





Model-independent presentation



Next: covariance matrix or likelihood before grouping ggF+ttH & VBF+VH

Note: All coupling measurements pass through this space

Updated CMS result

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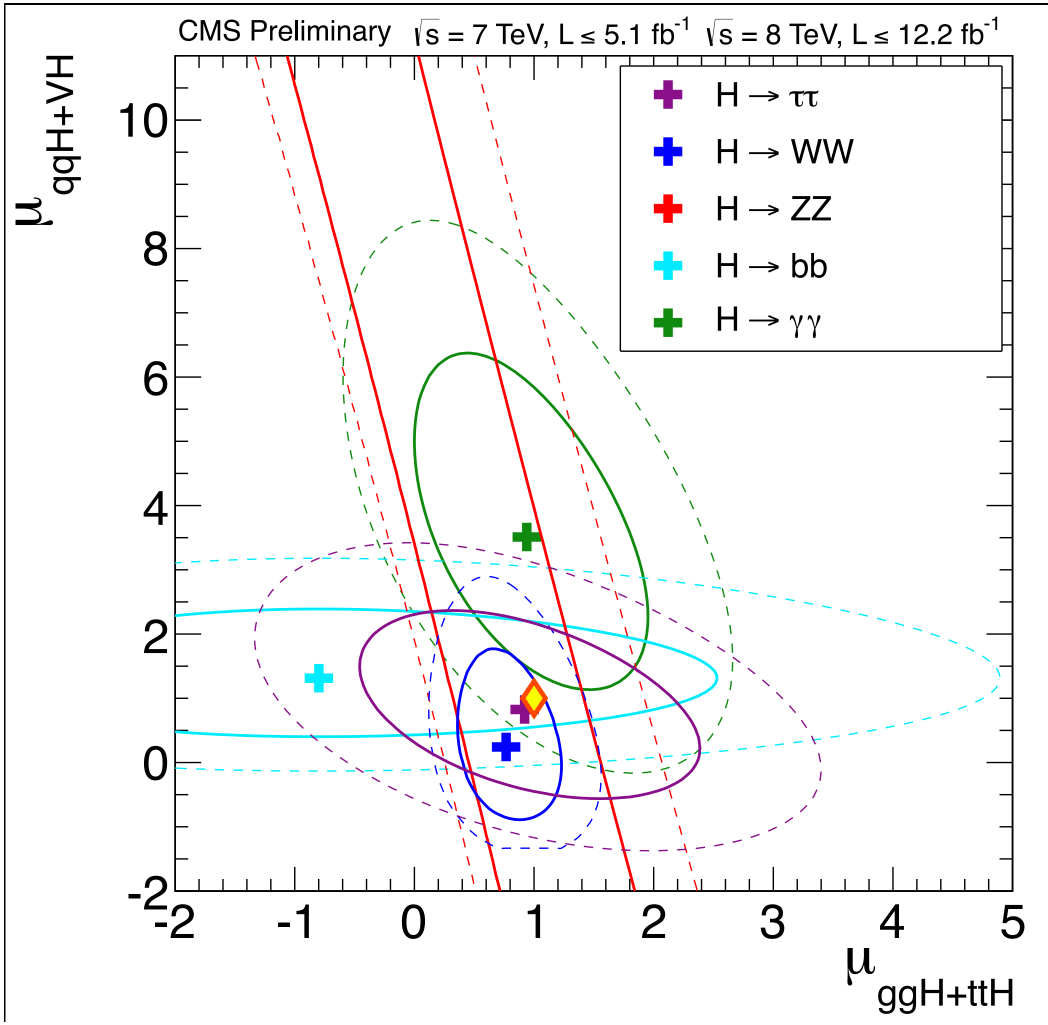
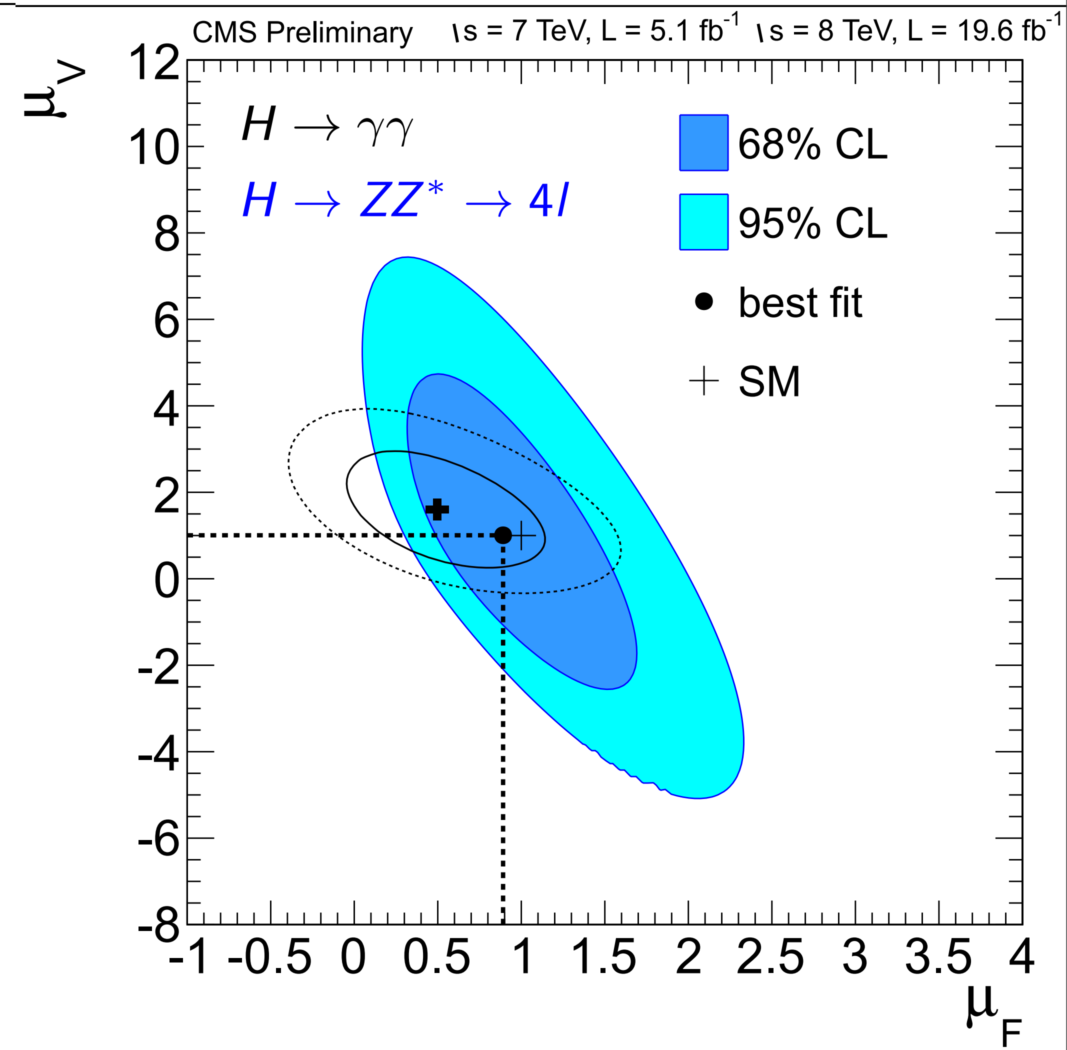
Unfortunately, H→$\gamma\gamma$ no longer high



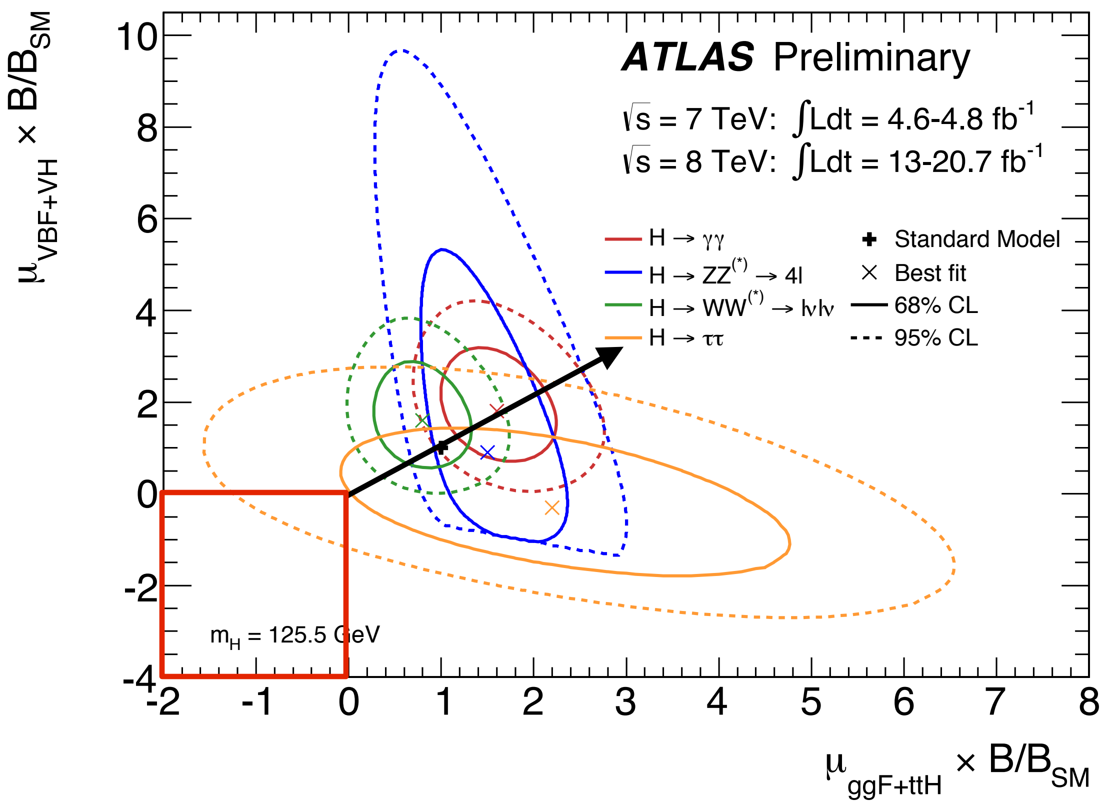


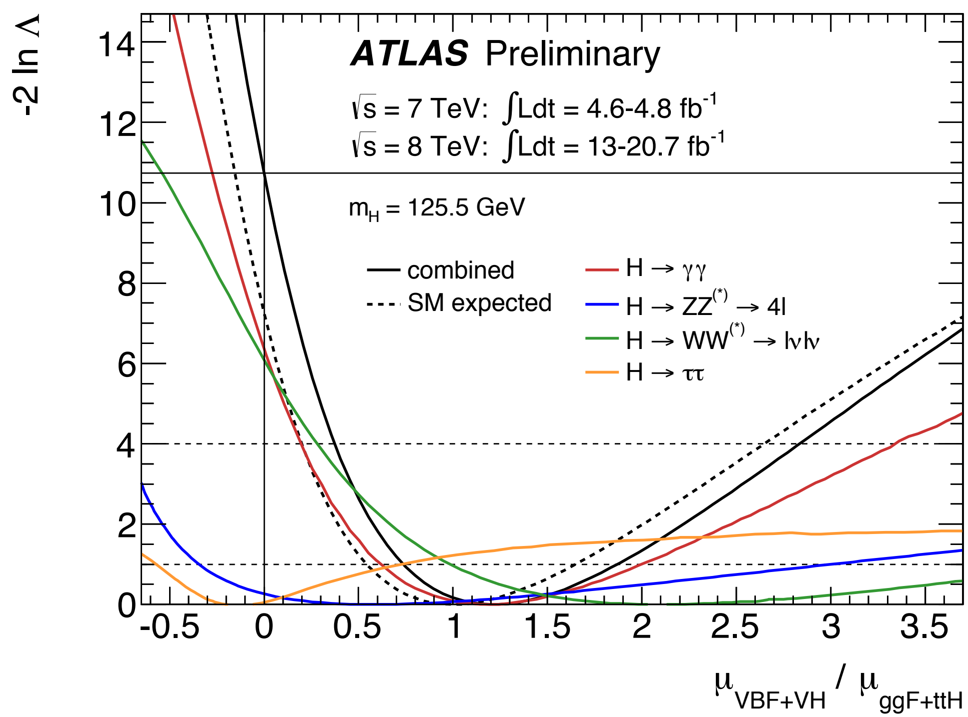
Model-independent presentation

Can't compare contours directly, b/c there is a different BR for axis

But, BR cancels when considering slope in this plane

- still sensitive to theory uncertainties (jet veto, ggH+2jet contamination,...)





~3σ evidence for VBF Higgs production!

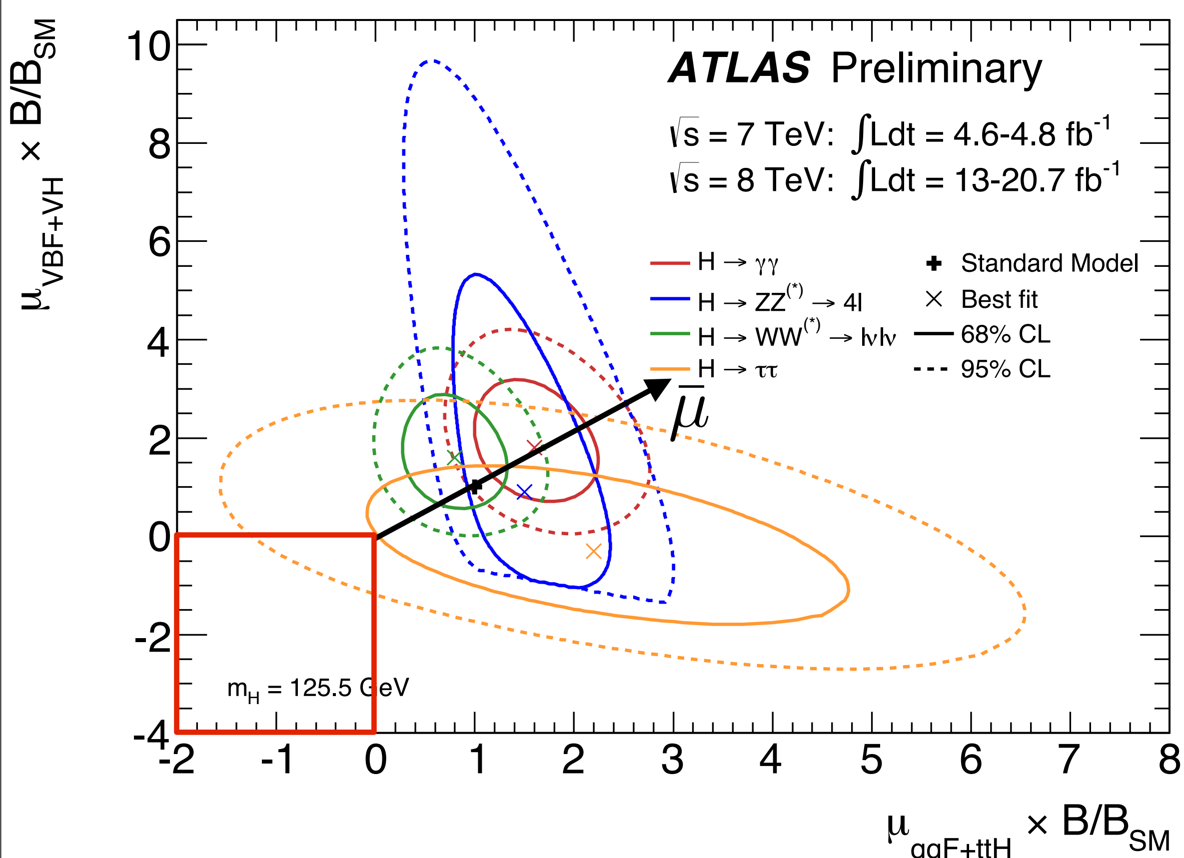
Ratio of Branching Ratios

Anything that relies on σ_{ggF} subject to reasonably large theoretical uncertainty (thus hard to make claim of BSM physics)

- Measure ratio of branching ratios instead

Not trivial with multiple production modes b/c cross-section doesn't cancel

$$L\left(\bar{\mu}\frac{BR(\gamma\gamma)}{BR_{\rm SM}(\gamma\gamma)}\right) L\left(\bar{\mu}\frac{BR(ZZ)}{BR_{\rm SM}(ZZ)}\right) \to L\left(\underbrace{\bar{\mu}\frac{BR(ZZ)}{BR_{\rm SM}(ZZ)}}_{NP} \underbrace{\frac{BR(\gamma\gamma)}{BR(ZZ)}\frac{BR_{\rm SM}(ZZ)}{BR_{\rm SM}(\gamma\gamma)}}_{\rm POI}\right) L\left(\underbrace{\bar{\mu}\frac{BR(ZZ)}{BR_{\rm SM}(ZZ)}}_{NP}\right)$$



1. Profile on $\frac{\mu_{\rm ggF+ttH}}{\mu_{\rm VBF+WH}}$
2. Overall $\bar{\mu}$ production cancels
3. Measure: $\frac{BR(\gamma\gamma)}{BR(ZZ)}\frac{BR_{\rm SM}(ZZ)}{BR_{\rm SM}(\gamma\gamma)}$

Ratio of Branching Ratios

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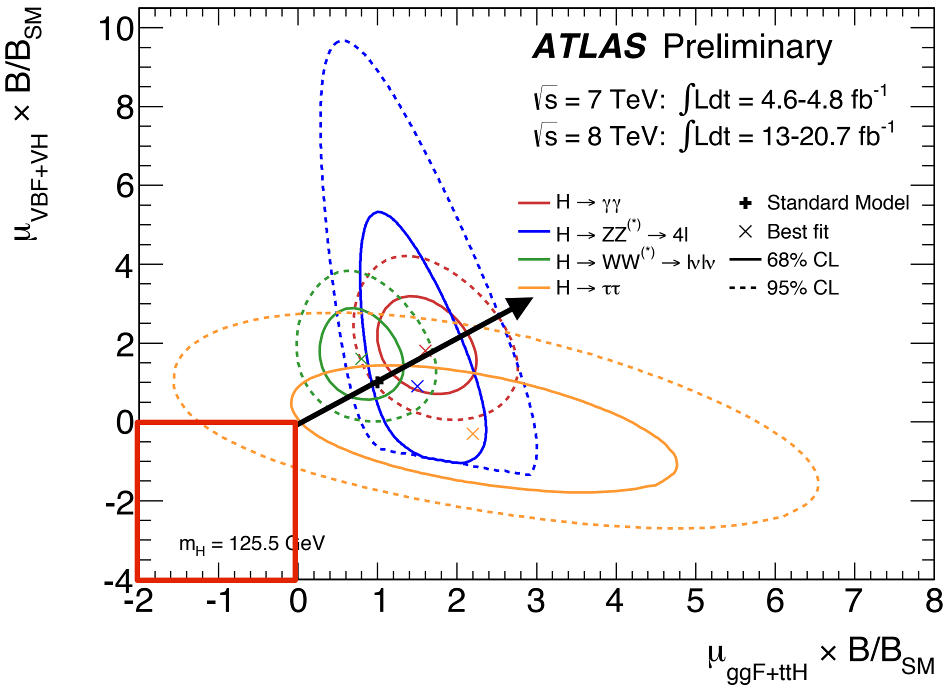
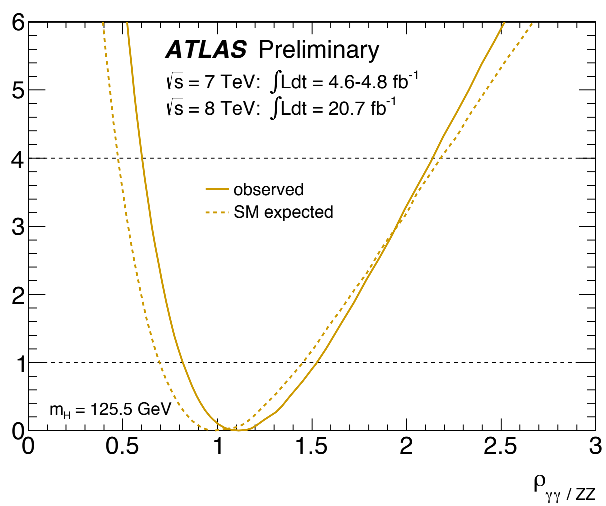


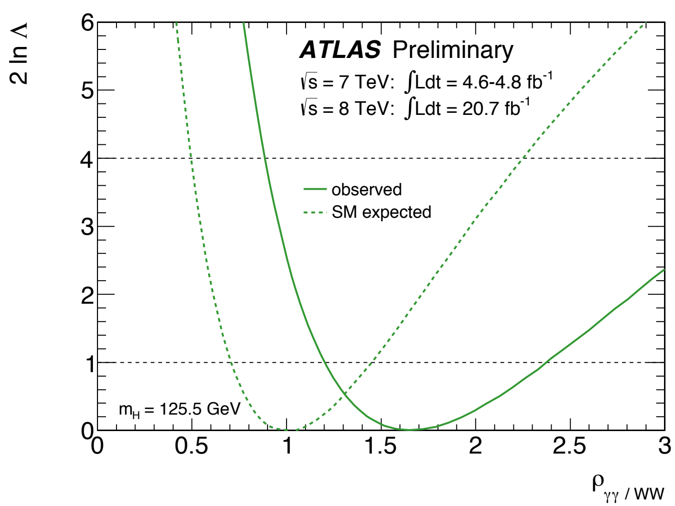
$$\rho_{\gamma\gamma/ZZ} = \frac{\mathrm{BR}(H\to\gamma\gamma)}{\mathrm{BR}(H\to ZZ^{(*)})} \times \frac{\mathrm{BR}_{\mathrm{SM}}(H\to ZZ^{(*)})}{\mathrm{BR}_{\mathrm{SM}}(H\to\gamma\gamma)}$$

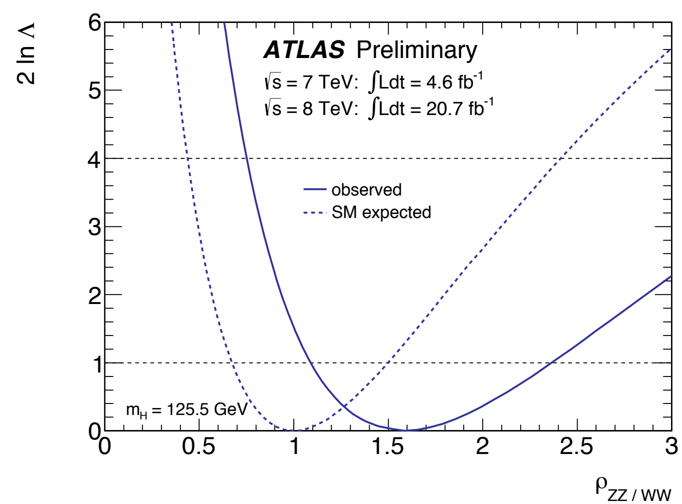
$$\rho_{\gamma\gamma/ZZ} = 1.1^{+0.4}_{-0.3}$$

$$\rho_{\gamma\gamma/WW} = 1.7^{+0.7}_{-0.5}$$

$$\rho_{ZZ/WW} = 1.6^{+0.8}_{-0.5}$$







Narrow width approximation

The basic starting point for the various parametrizations :

$$\sigma(H) \times \mathrm{BR}(H \to xx) = \frac{\sigma(H)^{\mathrm{SM}}}{\Gamma_p^{\mathrm{SM}}} \cdot \frac{\Gamma_p \Gamma_x}{\Gamma}$$

No useful direct constraint on total width at LHC

- ideally, allow for invisible or undetected partial widths
- leads to an ambiguity unless something breaks degeneracy

Various strategies / assumptions break this degeneracy

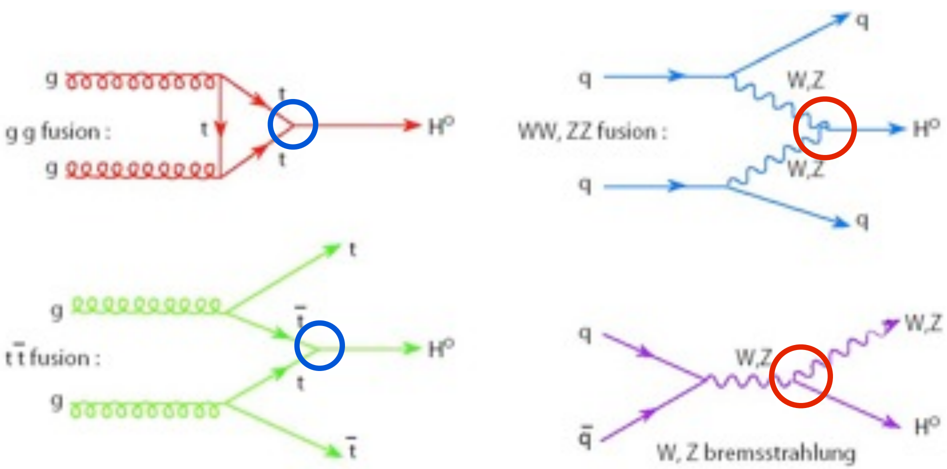
- Assume no invisible decays
- Fix some coupling to SM rate
- Only measure ratios of couplings
- Limit $\Gamma_V \leq \Gamma_V^{\mathrm{SM}}$ eg. Dührssen et. al, Peskin, ...
    - valid for CP-conserving H, no H^{++}, ... Gunion, Haber, Wudka (1991)
    - together with $\Gamma_V^2/\Gamma = \mathrm{meas} \quad \Rightarrow \quad \Gamma_{\mathrm{vis}} \leq \Gamma \leq \Gamma_{V,SM}^2/\mathrm{meas}$

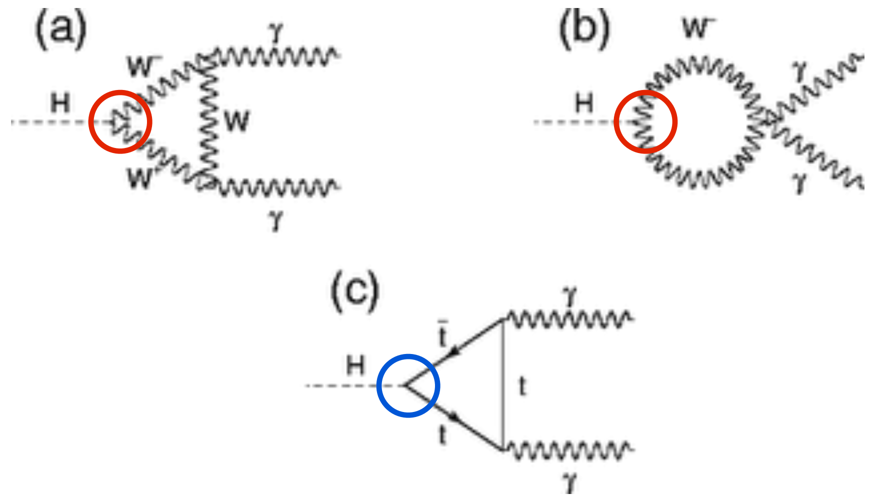
Parametrizing the couplings

Approach: scale couplings w.r.t. SM values by factor κ

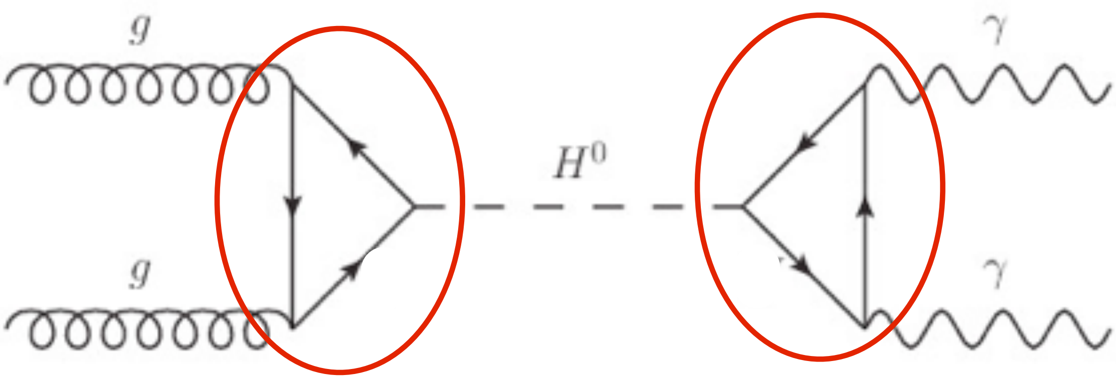
- Expansion around SM point with state-of-the-art predictions

Option 1) relate ggH and $\gamma\gamma$H assuming no new particles in loop





Option 2) introduce κ_g and κ_γ as effective coupling to ggH and $\gamma\gamma$H



Overview of parametrizations

Production modes

$$\frac{\sigma_{\mathrm{ggH}}}{\sigma^{\mathrm{SM}}_{\mathrm{ggH}}} = \begin{cases} \kappa^2_{\mathrm{g}}(\kappa_{\mathrm{b}}, \kappa_{\mathrm{t}}, m_H) \\ \kappa^2_{\mathrm{g}} \end{cases}$$

option 1/2

$$\frac{\sigma_{\mathrm{VBF}}}{\sigma^{\mathrm{SM}}_{\mathrm{VBF}}} = \kappa^2_{\mathrm{VBF}}(\kappa_{\mathrm{W}}, \kappa_{\mathrm{Z}}, m_H)$$

$$\frac{\sigma_{\mathrm{WH}}}{\sigma^{\mathrm{SM}}_{\mathrm{WH}}} = \kappa^2_{\mathrm{W}}$$

$$\frac{\sigma_{\mathrm{ZH}}}{\sigma^{\mathrm{SM}}_{\mathrm{ZH}}} = \kappa^2_{\mathrm{Z}}$$

$$\frac{\sigma_{\mathrm{t\bar{t}H}}}{\sigma^{\mathrm{SM}}_{\mathrm{t\bar{t}H}}} = \kappa^2_{\mathrm{t}}$$

Total width

$$\frac{\Gamma_{\mathrm{H}}}{\Gamma^{\mathrm{SM}}_{\mathrm{H}}} = \begin{cases} \kappa^2_{\mathrm{H}}(\kappa_i, m_H) \\ \kappa^2_{\mathrm{H}} \end{cases}$$

Detectable decay modes

$$\frac{\Gamma_{\mathrm{WW}^{(*)}}}{\Gamma^{\mathrm{SM}}_{\mathrm{WW}^{(*)}}} = \kappa^2_{\mathrm{W}}$$

$$\frac{\Gamma_{\mathrm{ZZ}^{(*)}}}{\Gamma^{\mathrm{SM}}_{\mathrm{ZZ}^{(*)}}} = \kappa^2_{\mathrm{Z}}$$

$$\frac{\Gamma_{\mathrm{b\bar{b}}}}{\Gamma^{\mathrm{SM}}_{\mathrm{b\bar{b}}}} = \kappa^2_{\mathrm{b}}$$

$$\frac{\Gamma_{\tau^-\tau^+}}{\Gamma^{\mathrm{SM}}_{\tau^-\tau^+}} = \kappa^2_{\tau}$$

$$\frac{\Gamma_{\gamma\gamma}}{\Gamma^{\mathrm{SM}}_{\gamma\gamma}} = \begin{cases} \kappa^2_{\gamma}(\kappa_{\mathrm{b}}, \kappa_{\mathrm{t}}, \kappa_{\tau}, \kappa_{\mathrm{W}}, m_H) \\ \kappa^2_{\gamma} \end{cases}$$

$$\frac{\Gamma_{\mathrm{Z}\gamma}}{\Gamma^{\mathrm{SM}}_{\mathrm{Z}\gamma}} = \begin{cases} \kappa^2_{(\mathrm{Z}\gamma)}(\kappa_{\mathrm{b}}, \kappa_{\mathrm{t}}, \kappa_{\tau}, \kappa_{\mathrm{W}}, m_H) \\ \kappa^2_{(\mathrm{Z}\gamma)} \end{cases}$$

Benchmark models

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Fully model independent fit is not very informative with current data

- Benchmarks proposed by joint theory/experiment LHC XS group

arXiv:1209.0040

Probe Fermionic vs. Bosonic couplings:

- relevant for Type I 2HDM

$$\kappa_F = \kappa_t = \kappa_b = \kappa_\tau$$
$$\kappa_V = \kappa_W = \kappa_Z$$

Probe W vs. Z couplings (custodial symmetry)

- note: current benchmark assumes nothing new in ggH and $\gamma\gamma$H loops!

Probe up. vs. down fermion couplings

Probe quark vs. lepton couplings

Probe new particles in ggH and $\gamma\gamma$H loops

Probe invisible decays

Information Geometry / Experimental Design

For a given experiment, there is a natural parametrization of the theory where the expected error ellipses are all unit circles ⇒ a metric on the original parameters

For couplings, the metric tensor for any theory can be written in terms of

- a (singular) matrix representing experimental information, and
- a Jacobian that depends only on the theory

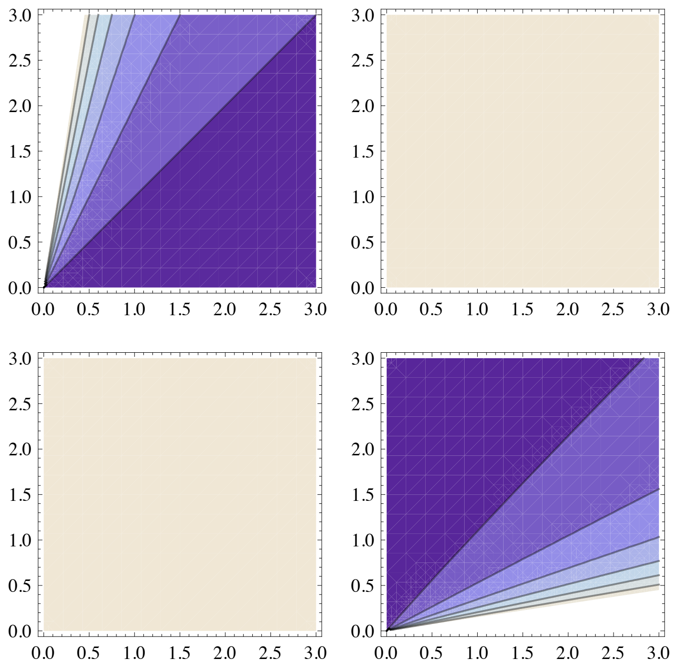
$$\mathcal{I}_{\boldsymbol{\eta}}(\boldsymbol{\eta}) = \boldsymbol{J}^{\mathrm{T}} \mathcal{I}_{\boldsymbol{\theta}}(\boldsymbol{\theta}(\boldsymbol{\eta})) \boldsymbol{J}$$

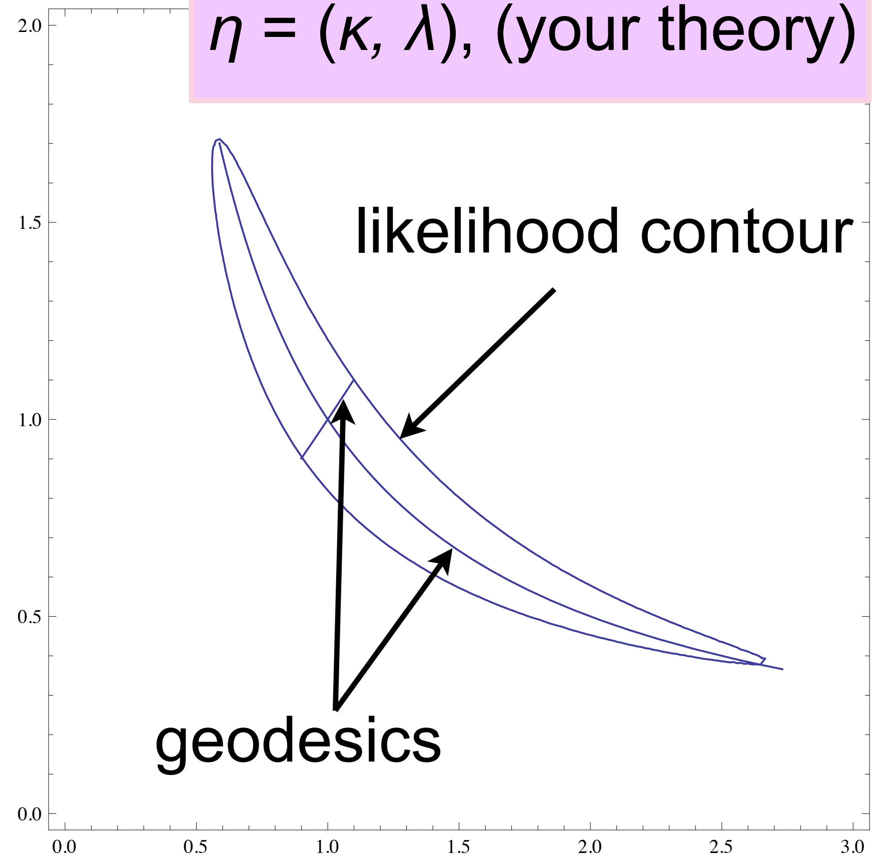
$\theta = (\sigma_i, BR_f)$

$\eta = (\kappa, \lambda)$, (your theory)

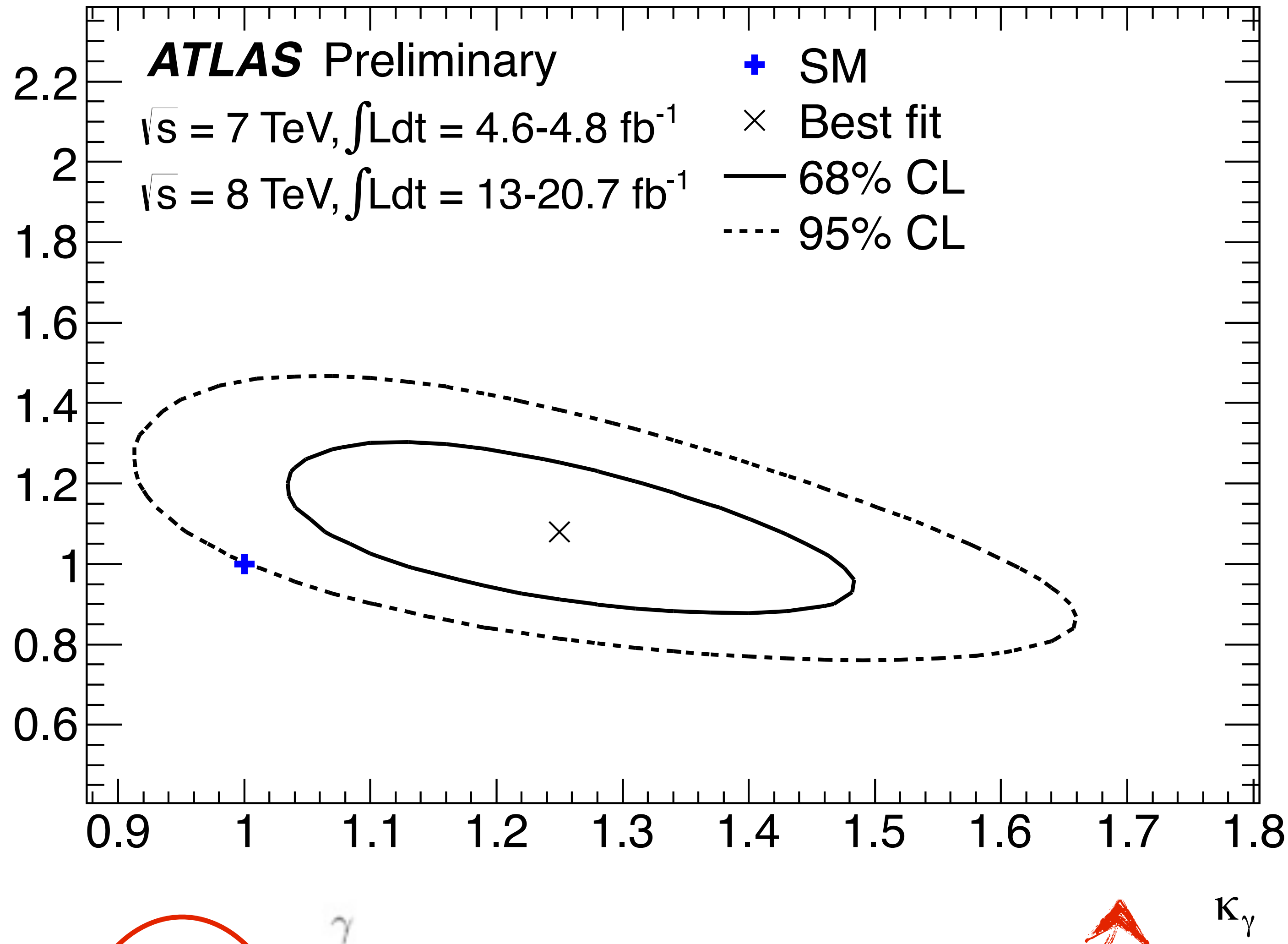
In example below the likelihood contour is reconstructed by following geodesics

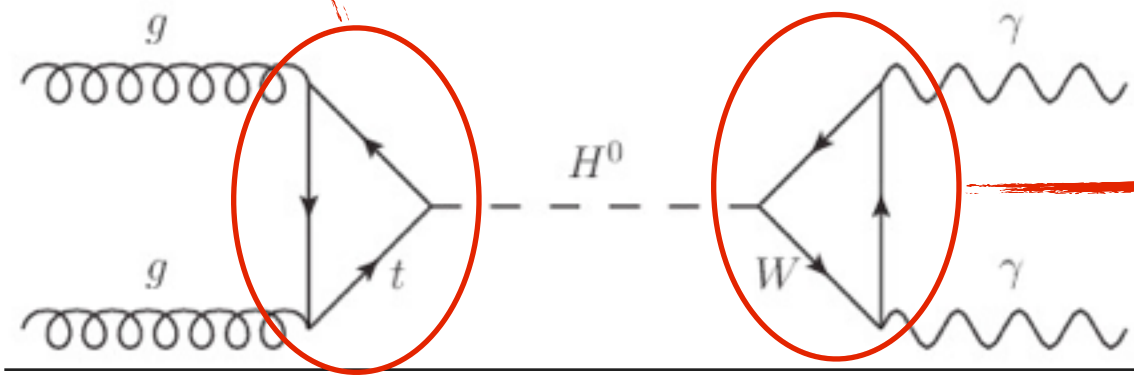
metric tensor





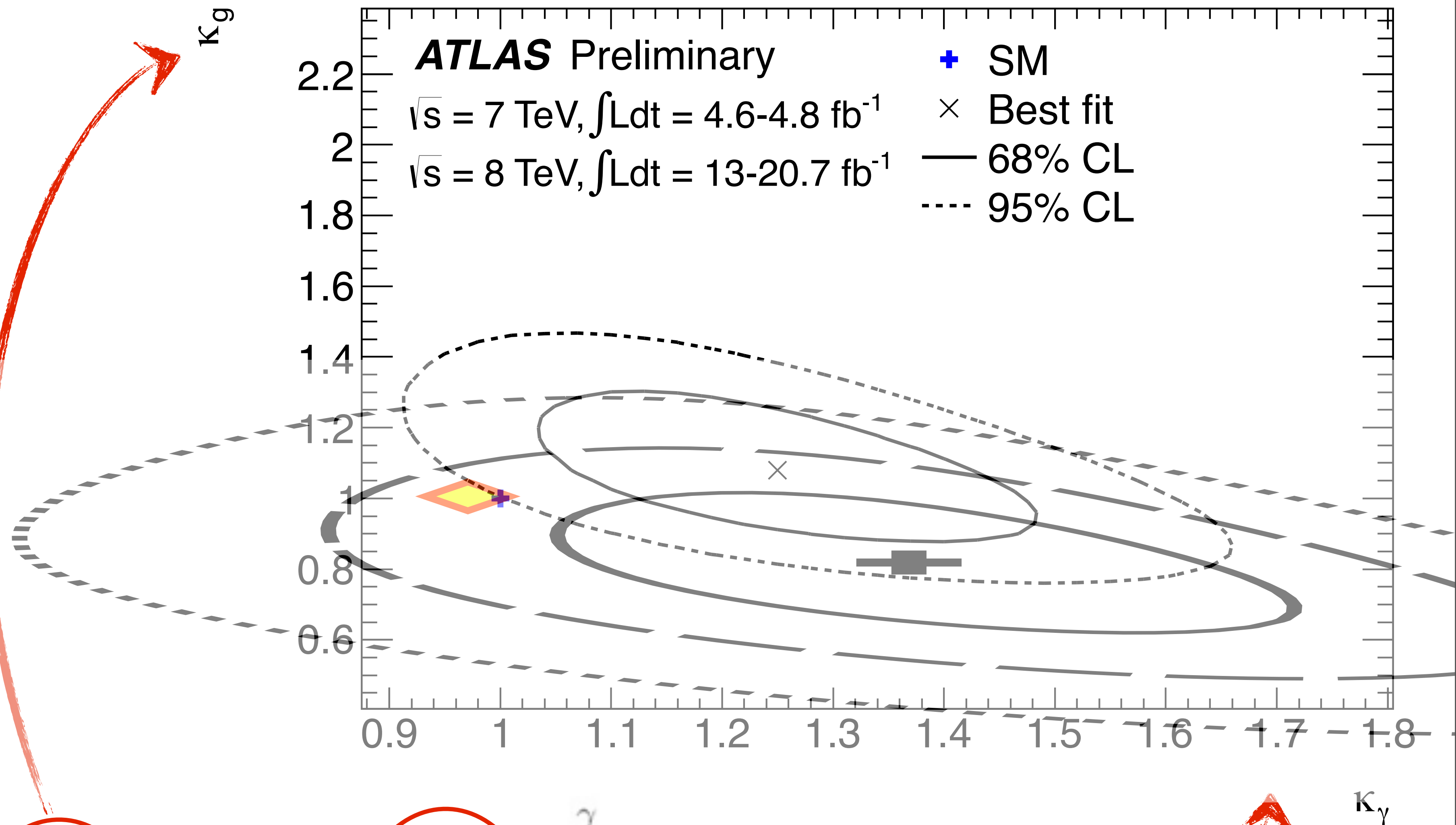
Probing new physics in loops

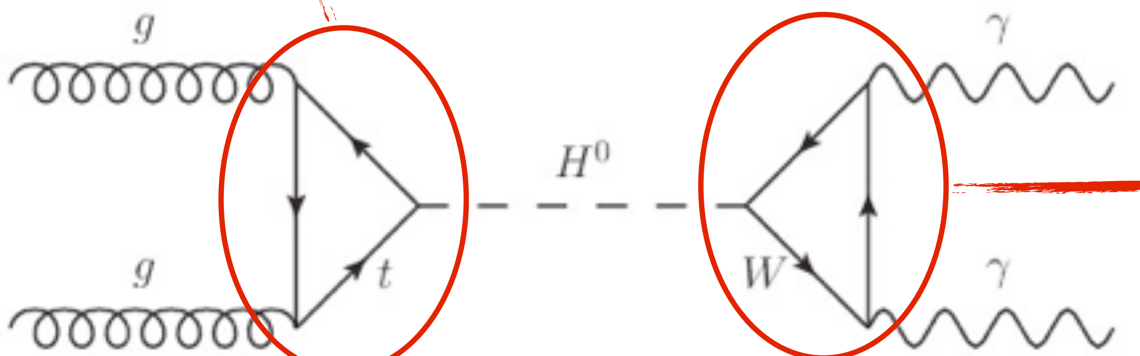




3x more data by the end of the year!

Probing new physics in loops





3x more data by the end of the year!

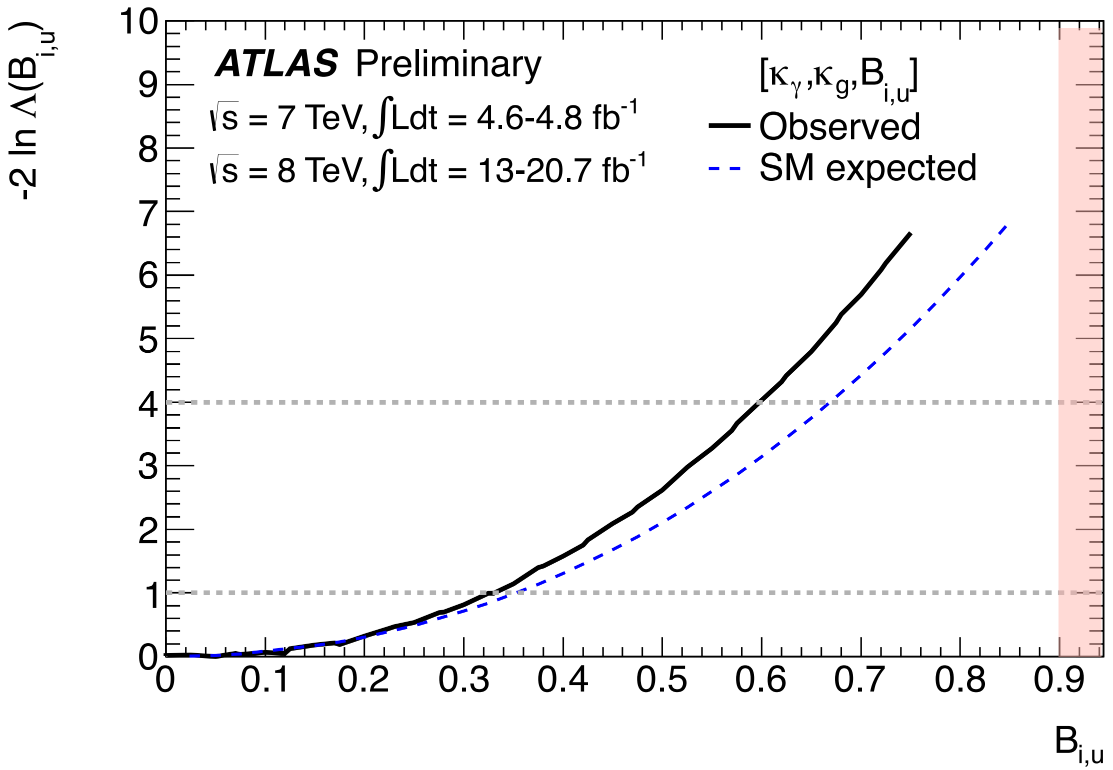
Probing invisible decays

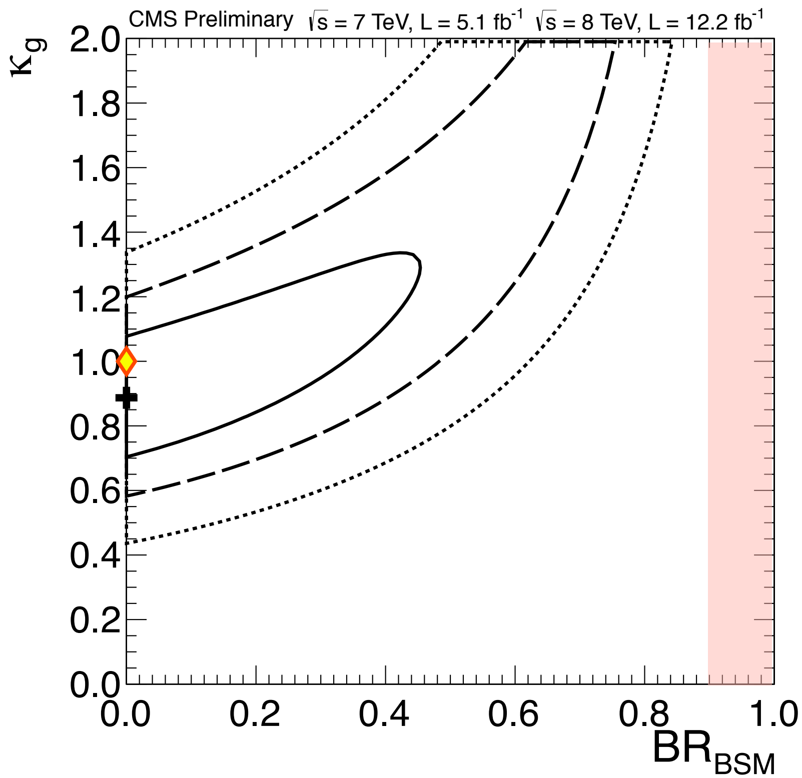
Here total width modified by: $$\Gamma_H = \frac{\kappa_H^2(\kappa_i)}{(1 - BR_{inv.,undet.})}\Gamma_H^{SM}$$

- uses effective coupling for ggH and $\gamma\gamma$H loops
- everything else is SM-like (namely VBF production)

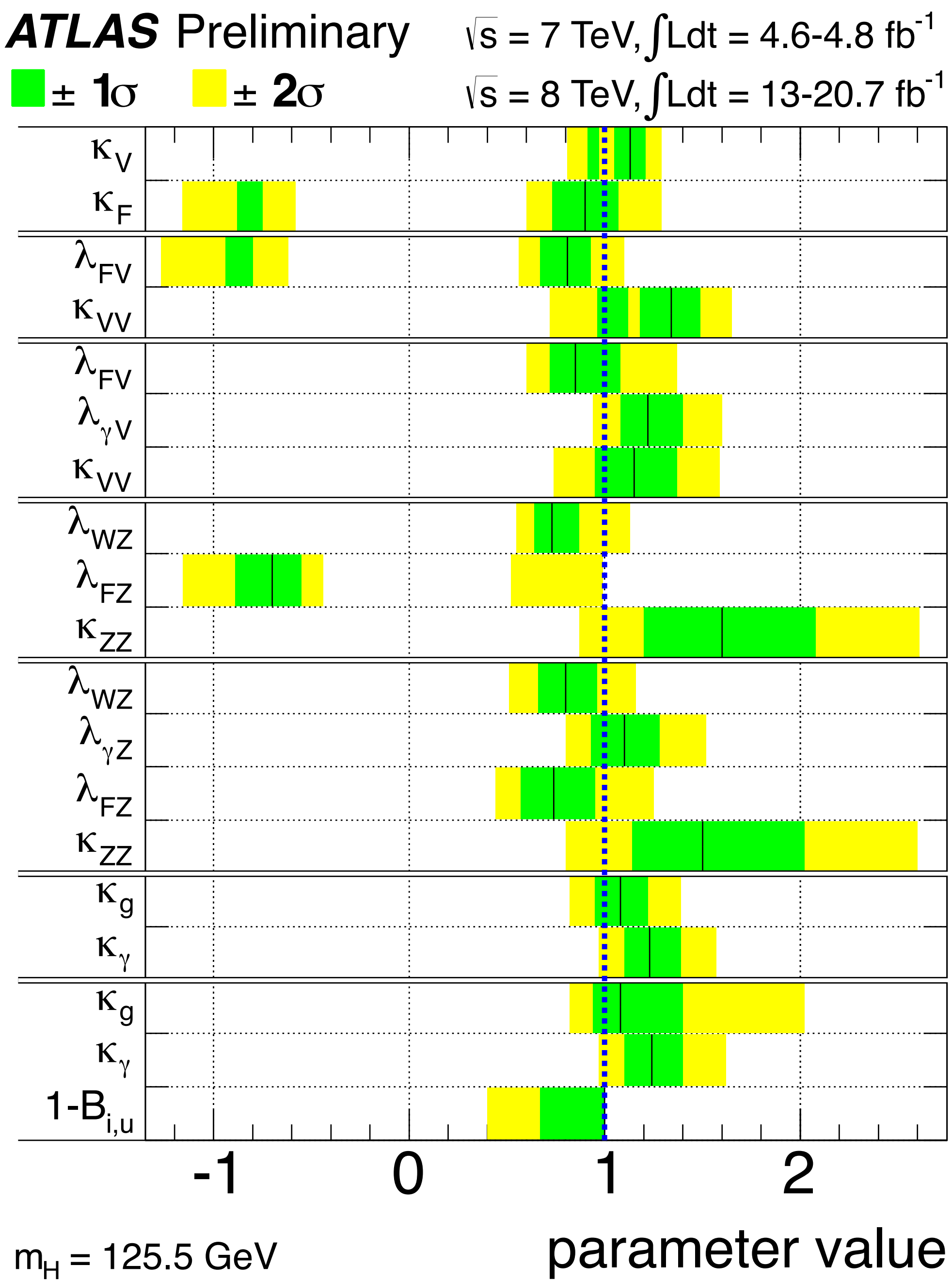
Disfavors large BR to invisible

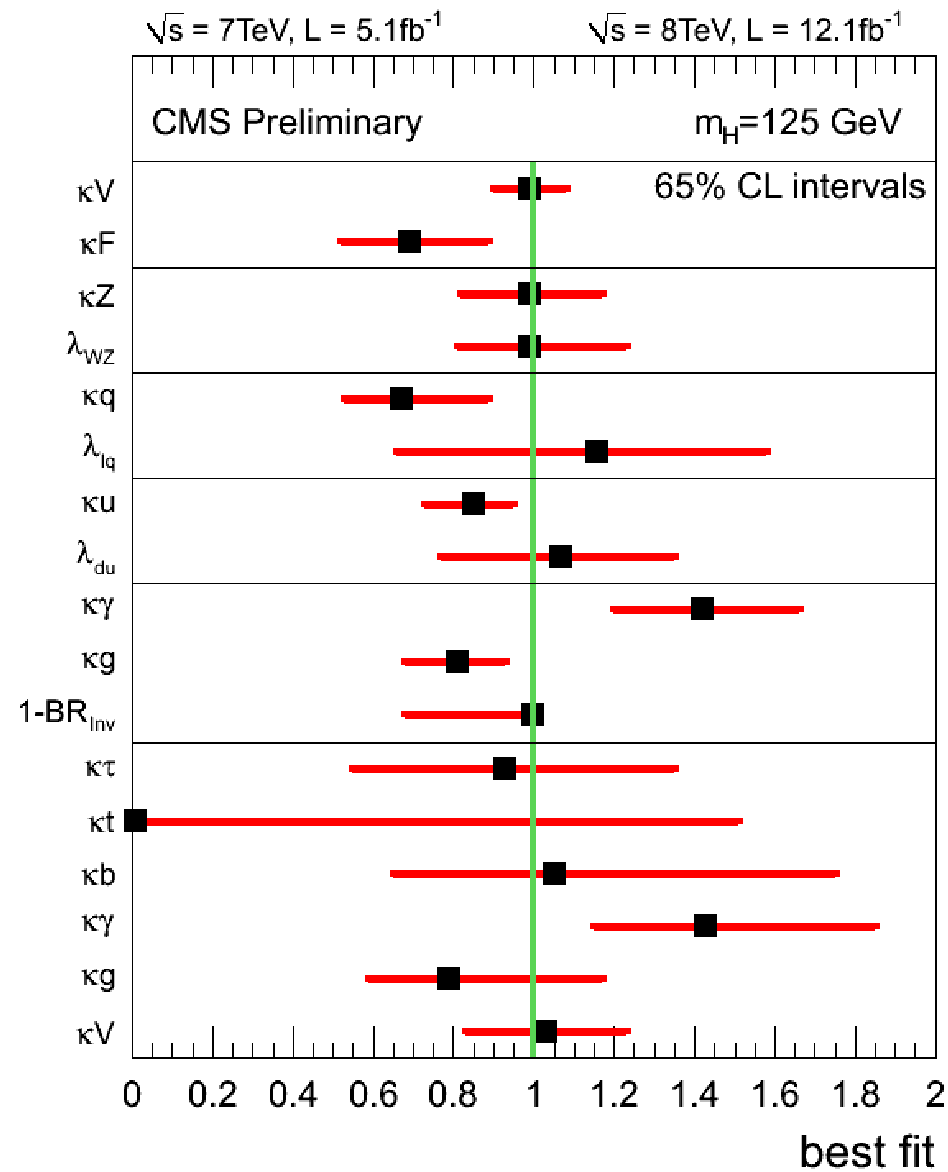
As BR(inv) increases, κ_g must increase
As $\kappa_g \to \infty$ B(gg)$\to$ B(gg)$_{SM}$ ~10%
Thus BR(inv) < 1-B(gg)$_{SM}$





Results from various fits

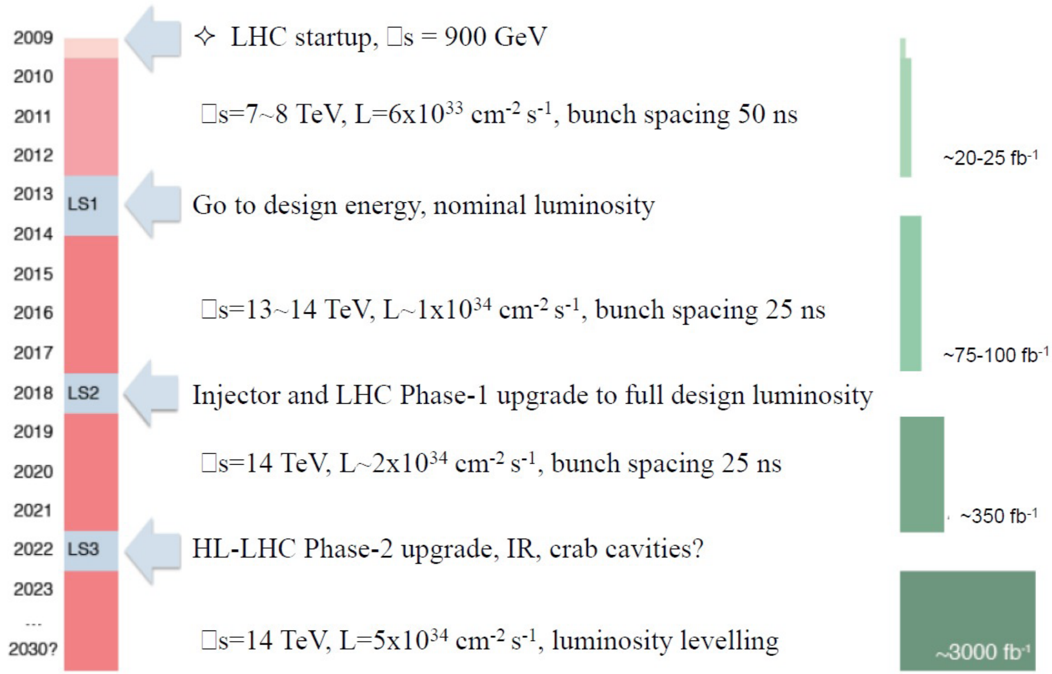




LHC potential for European Strategy

Bad timing:

- same few months as discovery and first property measurements
- limited effort available for these studies
- based on simplifications and assumptions about detector, how theory uncertainty evolves & systematics will scale with increased lumi, etc.



Higgs self coupling measurements feasible only at HL-LHC

→More challenging environment ($<\mu> \sim 140$):

Major detectors upgrades to cope with higher radiation levels, higher occupancy and required data rates:
-Replacement of critical components,
-Upgrades to trigger and electronics

E. Meoni (Aspen 2013)

ATLAS Projections

Center for Cosmology and Particle Physics

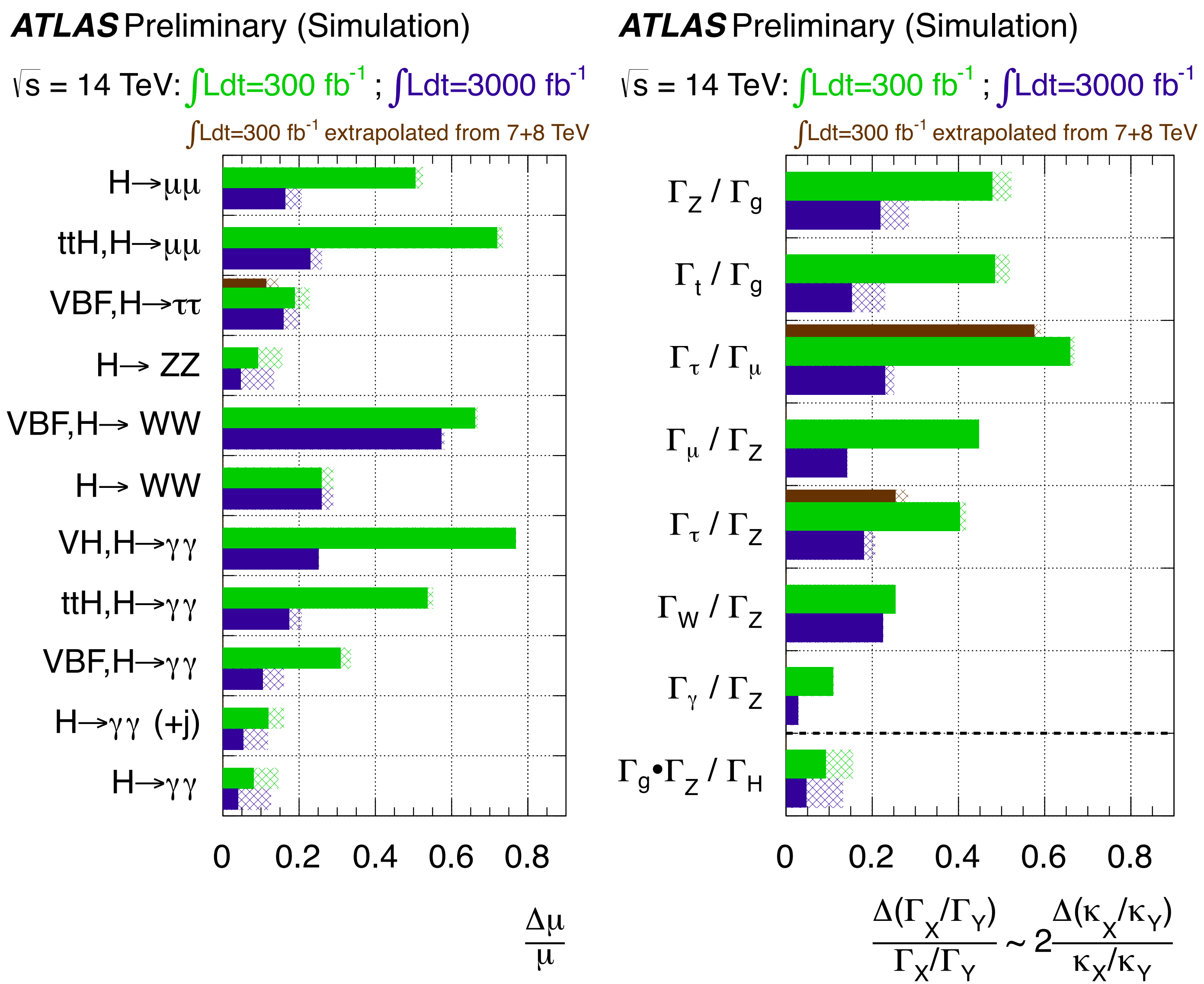
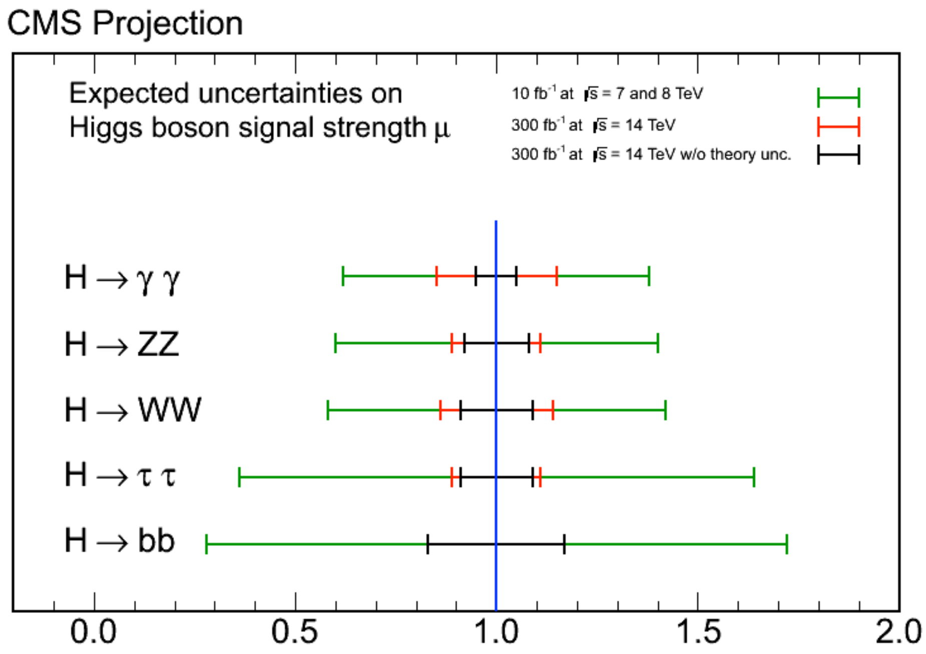


Figure 2.10: (a) Expected measurement precision on the signal strength in a selection of channels for 300 fb^{-1} and 3000 fb^{-1}. (b) Expected precisions on ratios of Higgs boson partial widths. In both figures the bars give the expected relative uncertainty for a SM Higgs with mass 125 GeV (dashed are current theory uncertainty from QCD scale and PDFs). The thin bars show extrapolations from current analysis to 300 fb^{-1}, instead of the dedicated studies for VBF channels.



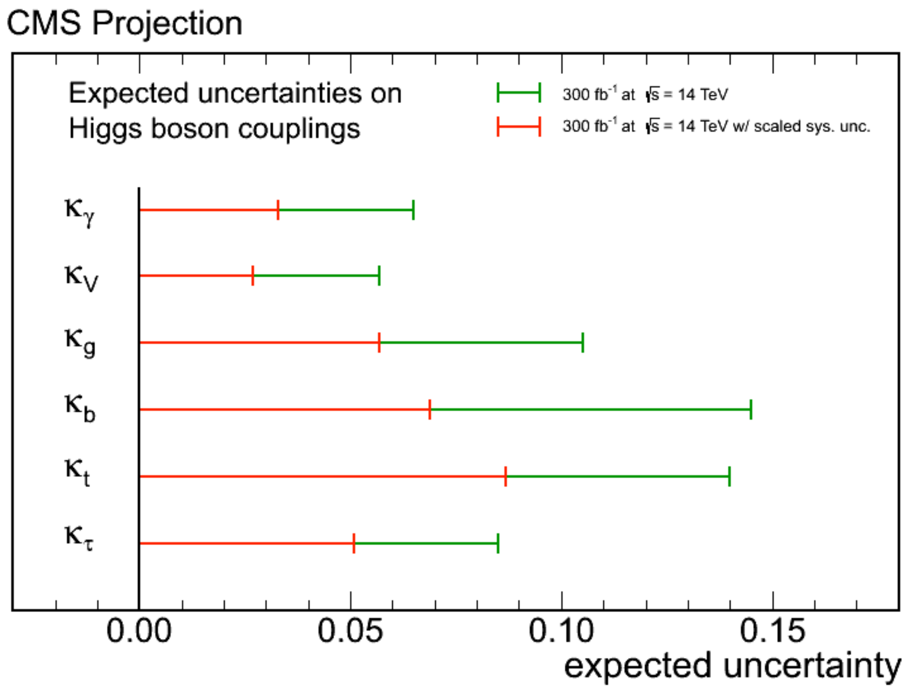


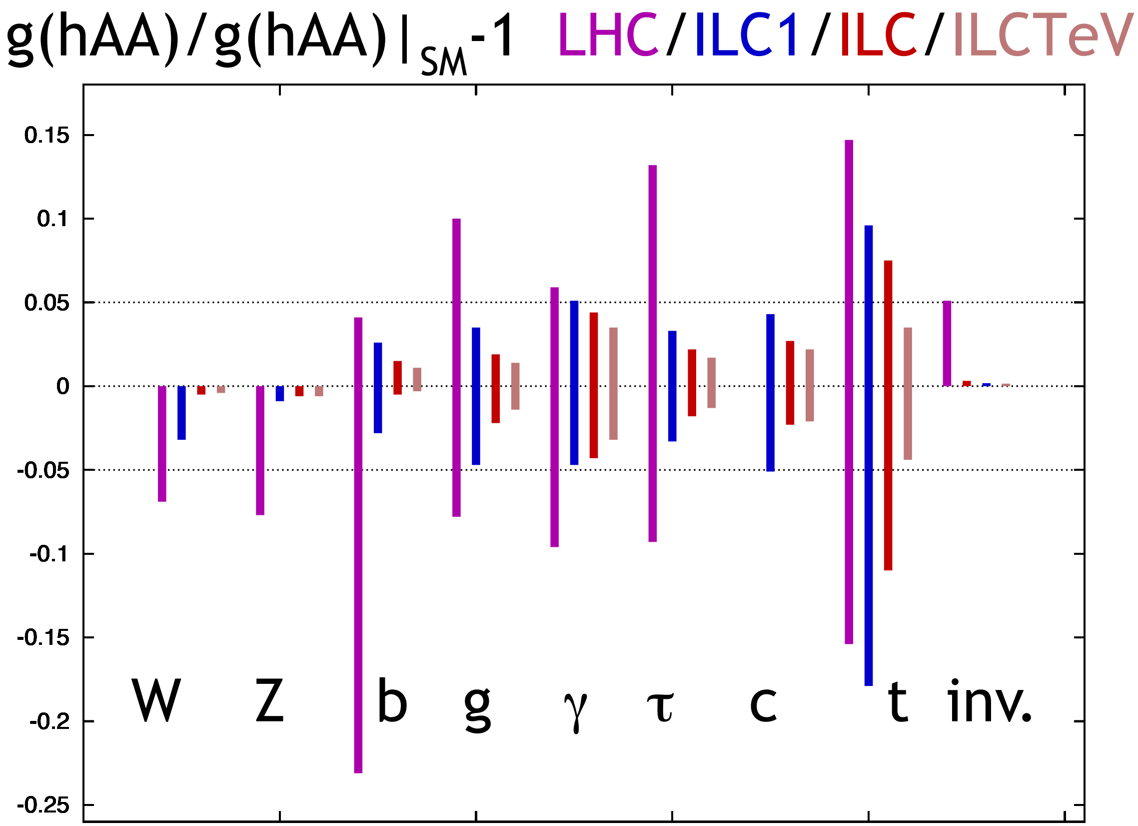
Figure 2.8: (Left) Estimated precision of the signal strength determination for a SM Higgs boson, from CMS. The projections assume $\sqrt{s} = 14$ TeV and an integrated luminosity of 300 fb^{-1}. They are shown including the current uncertainties and neglecting the systematic uncertainties from theory and are compared to the expected uncertainties of the measurement with 10 fb^{-1} at $\sqrt{s} = 7$ and 8 TeV. (Right) Estimated precision on the measurements of the couplings κ_γ, κ_V, κ_g, κ_b, κ_t, and κ_τ from CMS, for 300 fb^{-1} at $\sqrt{s} = 14$ TeV. The green line represents the precision attainable in the case where all systematic uncertainties are kept unchanged (present knowledge). The red line represents the precision achievable scaling the theoretical uncertainties by a factor of 1/2, while other systematic uncertainties are scaled by the square root of the integrated luminosity.

Status of the current projections

v3 appendix of M. Peskin's [arXiv:1208.5152] discussing European Strategy results

- understandable frustration with lack of documentation for these projections and poorly understood differences between ATLAS &CMS

What can be done to improve this situation for Snowmass?



Higgs self couplings

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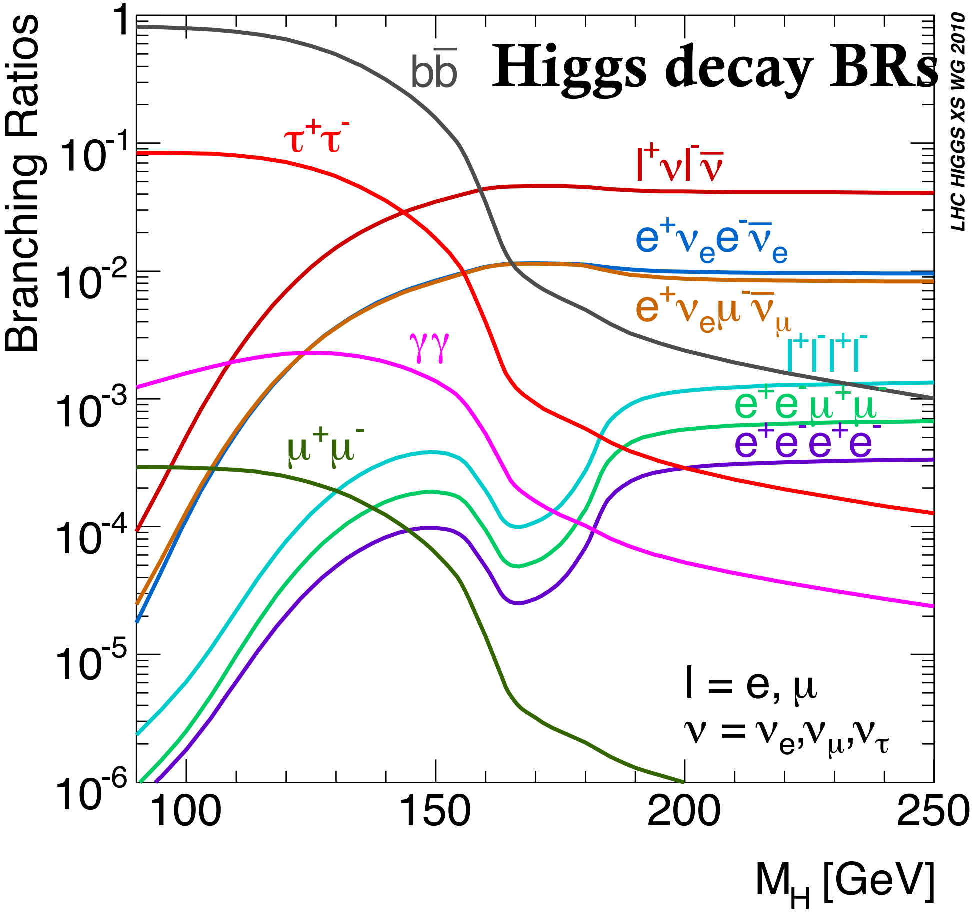


ATLAS-PHYS-PUB-2013-001

sample	$\sigma\times$BR (fb)	simulated events	events passing selection	events expected in 3000 fb^{-1}
$HH \to b\bar{b}\gamma\gamma$ ($\lambda_{HHH}=1$)	0.09	1020	42	10.7
$HH \to b\bar{b}\gamma\gamma$ ($\lambda_{HHH}=0$)	0.19	1020	32	17.9
$HH \to b\bar{b}\gamma\gamma$ ($\lambda_{HHH}=2$)	0.04	1230	66	6.4
$\gamma\gamma b\bar{b}$	111	3.1×10^4	1	1.1
$ZH(Z\to b\bar{b}, H\to\gamma\gamma)$	0.04	5×10^5	11600	2.8
$b\bar{b}H(H\to\gamma\gamma)$	0.124	5×10^4	71	0.5
$\gamma\gamma jj$	2×10^3	5×10^5	0.004	0.1
$jjjj$	1.8×10^8	4.6×10^6	0	0
$t\bar{t}H(H\to\gamma\gamma)$	1.71	1.2×10^5	379	13.6
$t\bar{t}$ ($\geq$ 1 leptonic W decay)	5.0×10^5	1×10^7	74†	1.1
Total Background	-	-	-	19.2

Consider: A Higgs-like Dilaton

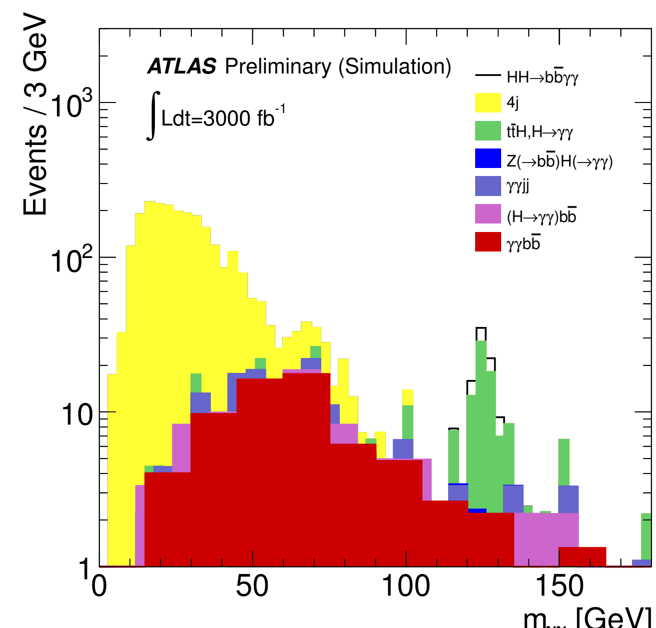
arXiv:1209.3299 (Bellazzini, et. al)

hard to distinguish from a SM Higgs

potential can deviate from quartic

$\Rightarrow$ deviations in self-couplings

(alternatively, probe 3TeV compositeness scale)



Conclusions

The measurement of Higgs properties is under way

- we have a working framework in which to perform these measurements
- some channels are already transitioning to systematics limited
- theoretical uncertainties are a big challenge

Our current projections for LHC potential are quite uncertain

- we don't want to make our physics case on overly optimistic or pessimistic projections
  - Don't mis-underestimate how clever we can be with time
  - it's hard to plan on these improvements, when the strategy for achieving them is not yet in place.

Higgs coupling measurements in scenario where we observe non-standard production or decay are also interesting